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AN EXPERIMENTAL COMPARISON OF THE RELATIVE EFFECTIVENESS OF TWO PROBLEM SOLVING PROCEDURES TAUGHT TO EDUCABLE MENTALLY RETARDED BOYS

by

HENRY H. UNRAU

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance a thesis entitled AN EXPERIMENTAL COMPARISON OF THE RELATIVE EFFECTIVENESS OF TWO PROBLEM SOLVING PROCEDURES TAUGHT TO EDUCABLE MENTALLY RETARDED BOYS, submitted by HENRY HAROLD UNRAU in partial fulfilment of the requirements for the degree of Master of Education.

ABSTRACT

Problem-solving ability is closely linked with thinking and reasoning ability. A study of the problem-solving abilities of the educable mentally handicapped could result in an increased understanding of their thinking and reasoning abilities and processes. The present study was designed to compare the effectiveness of two problem-solving procedures, a "rule method" and a more abstract "discovery method". These methods were based on procedures recommended and used in current arithmetic textbooks.

Thirteen matched pairs of educable mentally retarded boys were divided into two experimental classes. One randomly-chosen class was taught the "rule method" and the other the "discovery method" of solving problems in arithmetic.

The *California Arithmetic Test* was administered to all students in September and again in May to measure progress. As a check on the results of the test, the grades three and five problem-solving sections of the *Iowa Tests of Basic Skills* were also administered at these times. The differences between the mean gains of the two classes on the test measures were analysed, using both a nonparametric Walsh test and a parametric t-test.

No significant differences between the mean gains of the two classes were found. However, it was interesting to observe that, (1) both experimental groups achieved satisfactory gains on the Arithmetic Reasoning portion of the *California Arithmetic Test*, and (2) the differences on all test measures favored the class taught the "discovery method" of solving problems.

It could be inferred from the results of the study that systematic instruction in problem-solving procedures benefitted both experimental classes. In addition, the class taught the "discovery method" was not harmed by using procedures recommended in recent arithmetic textbooks.

Due to the many difficulties encountered in attempting large-sample research studies, long-term studies involving fewer subjects should be considered. Classroom research by the teacher, if properly guided and directed, could aid in compiling a large body of data concerning the learning, thinking and problem-solving abilities of the educable mentally retarded.

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CHAPTER I

THE PROBLEM AND DEFINITION OF TERMS

1. NEED FOR THE STUDY

One important objective of the arithmetic program in elementary and secondary schools is to develop students' problem solving abilities. For teachers of retarded students this is a particularly difficult task. Henderson and Pingry stated, "It is important that specific experiences designed to foster problem-solving abilities be provided in the program of instruction."[1] Research findings, however, are not in agreement as to what specific experiences are most effective in fostering the problem-solving abilities of educable mentally retarded students. Contradictory recommendations for the teaching of problem-solving to slow learners can be found in the literature. For example, Henderson and Pingry suggested that teachers could help slow learners improve in problem-solving abilities by not requiring step-by-step procedures to be followed, as a requisite sequence might cause them to lose sight of the pattern of relationships involved in the problem.[2] However, Johnson concluded that systematic and persistent training in problem-solving procedures was especially effective for children having less than average ability.[3]

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[1] Kenneth B. Henderson and Robert E. Pingry, "Problem Solving in Mathematics," The Twenty-First Yearbook of the National Council of Teachers of Mathematics (Washington, D.C.: The National Council of Teachers of Mathematics, 1953), p. 248.

[2] *Ibid.*, pp.265-266.

[3] Harry C. Johnson, "Problem Solving in Arithmetic: A Review of The Literature," Elementary School Journal 44: 396-403,March, 1944: 476-482, April, 1944.

While the lack of conclusive research evidence does not make the teaching of problem-solving to educable mentally retarded students any easier, other factors must also be considered. The program of arithmetic instruction is changing. Recent textbooks have recommended different approaches to arithmetic instruction, including different approaches to problem-solving. Can educable mentally retarded students profit from the methodology recommended in the new texts?

II. STATEMENT OF THE PROBLEM

The present study was undertaken to compare the relative effectiveness of two problem-solving procedures in arithmetic. The subjects of the study were two matched groups of educable mentally retarded boys attending intermediate opportunity classes. The two problem-solving procedures which were taught have been labelled arbitrarily the "rule method" and the "discovery method."

III. DEFINITION OF TERMS

The Two Methods

Each of two experimental classes was taught to solve problems using one of the two methods described below. Both classes solved problems presented to them in multigraph form.

The "rule method." Students in the class taught to solve problems using the "rule method", which was based on problem-solving procedures recommended in the Study Arithmetic series of arithmetic texts, proceeded in the following manner:

1. Students and teacher read the problems orally to eliminate vocabulary difficulties.

2. The students examined the problem and underlined the question part of each problem to focus attention on what was asked.

3. Context clues, cue words and the information given in each problem was studied; and students indicated what process or processes should be used in seeking a solution to the problem.

4. The indicated computation was completed in the space provided on the problem sheet.

5. The students re-read the problem to confirm that the question had been answered.

The "discovery method." Students in the class taught to solve problems using the "discovery method," which was based on problem-solving procedures recommended in the Seeing Through Arithmetic series of arithmetic textbooks, proceeded as follows:

1. Students and teacher read the problems orally to eliminate any vocabulary difficulties.

2. Students were encouraged to talk about or discuss the story or situation presented in each problem and make up a similar problem of their own.

3. Where feasible, the students drew diagrams to represent the problem situation.

4. Students translated the problem into a mathematical sentence or equation, representing the unknown by a symbol.[4]

5. The unknown quantity in the equation was replaced by the answer, or an answer, to the problem. Computation per se was not stressed and pupils were not required to show their work or indicate

---

[4] The symbol most favored was a box which could be used to contain the answer, thus eliminating the need to rewrite the equation.

the arithmetical process or processes they had used to find a solution to the problem.

Problem

For purposes of the study, a problem was defined as a mathematical question proposed for an answer or solution, which required the student to decide upon the operation or operations to be performed.

Educable Mentally Retarded

Those children whose mental development is so retarded that they cannot cope with the regular classroom program but can profit from a special program are usually termed educable mentally retarded or educable mentally-handicapped children. These two terms, as well as the abbreviation E.M.R., are used interchangeably in the present report.

Opportunity Class

In Edmonton, a class for the educable mentally retarded or educable mentally-handicapped is called an opportunity class. Intermediate opportunity classes include children between the ages of thirteen and fifteen.

IV. DESIGN OF THE STUDY

Thirteen pairs of students were selected from thirty-nine educable mentally retarded boys registered for placement in the intermediate boys' opportunity classes at Queen's Avenue School. The students were matched, or paired, as closely as possible, considering the limited size of the population, on the basis of chronological age, intelligence quotients, mental age and arithmetic achievement scores. Partners were randomly assigned to one or the other of the two experimental classes.

Two tests, the Arithmetic Reasoning portion of the _California Arithmetic Test_, upper primary or elementary level, and the grade three and grade five problem-solving sections of the _Iowa Tests of Basic Skills_, were administered at the end of September as pre-tests. At the end of May equivalent forms of these tests were administered as post-tests to compare the mean gains made by the two classes during the eight months the study was in progress.

Each class had four fifty-minute arithmetic periods each week. A portion of each arithmetic period was spent teaching the students to solve problems using the procedures outlined for their particular class. Teacher-made problem sheets, each containing eight problems ranging in difficulty from a grade three to a grade six level, were used with both classes to keep the problem solving content the same for both classes . The remainder of each arithmetic period was devoted to a regular program of arithmetic instruction with students using the _Winston Arithmetics_ textbook suitable for their achievement level.[5]

V. ASSUMPTIONS AND LIMITATIONS

Before the subjects could be matched and, again, before any results could be considered, it was necessary to make certain assumptions regarding intelligence scores used for matching and concerning the testing instruments used to measure progress in problem-solving ability during the eight-month study.

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[5] H.L. Stein, J. W. Gilles, E. Hodgson and A.F. Deverell(ed.), _Winston Arithmetics_ (Toronto: The John C. Winston Co. Ltd., 1954), _Discovering Numbers_, _Learning Numbers_, _Exploring Numbers_ and _Understanding Numbers_.

Assumptions

1. Intelligence scores considered for matching students were Stanford-Binet or W.I.S.C. individual intelligence test scores. The two tests were considered equal in their ability to measure intelligence, and test scores were considered equivalent. Thorndike and Hagen stated that while no directly comparable data were available, "Prediction of academic success can apparently be made about equally well from either test."[6]

2. While the most recent intelligence test scores available were considered for matching, many students had not been tested since entering opportunity classes three or more years earlier. Honzik, McFarlane and Allen conducted a study to measure the stability of the I.Q., over a period of time, using the Stanford-Binet intelligence test.[7] Thorndike and Hagen, discussing the findings of this study, stated:

> A test given at age eight or nine correlates .88 with one at age ten and still correlates .86 with one at age fourteen or fifteen.[8]

For the purposes of the present study the most recent intelligence score available for each subject was considered sufficiently stable to be accepted as a true measure of his intelligence at the time of matching.

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[6] Robert L. Thorndike and Elizabeth Hagen, Measurement and Evaluation in Psychology and Education (New York: John Wiley & Sons, Inc., 1961) p.231.

[7] Marjorie P. Honzik, J. W. McFarlane and Lucille Allen, "The Stability of Mental Test Performance Between Two and Eighteen Years," Journal of Experimental Education: 7: 1948, pp.309-324.

[8] Thorndike and Hagen, op.cit., p.245.

3. For the purposes of the present study, the Arithmetic Reasoning portions of the elementary and upper primary levels of the California Arithmetic Test were considered equally valid measures of problem-solving ability and problem-solving progress.[9] The upper primary level of the test was administered to all boys who scored below grade 4.4 on the arithmetic scores considered for matching. Those scoring grade 4.4 and over were given the elementary level of the test.

4. The Arithmetic Reasoning portion of the California Arithmetic Test, elementary or upper primary level, Forms X and W, was assumed to measure problem-solving ability, and Forms X and W, elementary and upper primary levels, were assumed to measure problem-solving equally well.[10]

5. The grades three and five problem-solving tests contained in Iowa Tests of Basic Skills, Forms One and Two, were read to the pupils before they began the test; and difficult words were pronounced for pupils during the testing period. Instructions for administering the test were modified further by having pupils work through each

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[9] The Technical Report on the California Achievement Tests, 1957 Edition, published by the California Test Bureau, Monterey, California, reported comparisons drawn between grade placement scores for successive levels of the California Arithmetic Tests and gave the standard deviation of the differences between the upper primary and elementary Arithmetic Reasoning grade placement scores as .654 (page 47). This standard deviation would include all error indicated by the standard error of measurement for each test at the two levels in addition to the error due to lack of articulation of the tests. The report stated on page 48 that: "The error above the standard error of measurement that can be attributed to lack of articulation between the grade placement scales for the various levels of the test is small."

[10] The Technical Report also stated on page 10 that, "Structurally and statistically they (the alternative forms of the test) are equivalent."

problem recording their answers as they did so. (The test requires only that the students indicate which of four possible responses is correct.) In addition, time limits were increased by five minutes to make a total testing period of thirty-five minutes.[11] Although such modifications invalidate the grade placement scores, the difference scores recorded were assumed to be realistic differences resulting from a change in problem-solving ability during the eight-month experiment.

Limitations

The present study was limited to a comparison of the problem-solving abilities of two classes of educable mentally retarded boys selected from the thirty-nine intermediate opportunity class boys who had attended opportunity classes during May of the previous school term and were sufficiently able to obtain a grade placement score on the California Arithmetic Test administered in May, 1961.[12]

Holt reported that approximately 1.2 per cent of the elementary school population in the Canadian school systems he surveyed was enrolled in opportunity classes.[13] This 1.2 per cent included students ranging in age from six to twenty. As only educable mentally retarded boys, ranging in age from thirteen to fifteen years, and attending intermediate opportunity classes in Edmonton were eligible for selection in the sample, but a small percentage of the total school population was considered in the present study.

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[11] The modifications in the directions for administering the Iowa Tests are discussed again on page 30.

[12] Appendix A contains the data considered in matching students.

[13] P.W.R. Holt, Administrative Practices Concerning the Educable Mentally Retarded in Selected Canadian Public Schools (unpublished Master's Thesis, The University of Alberta, Edmonton, 1962), p.44.

Due to the small population, the thirteen matched pairs comprising the two experimental classes could not be matched more closely than indicated by the following mean absolute differences between partners:

1. Chronological age: mean absolute difference was four months.
2. Intelligence Quotients: mean absolute difference 2.4 points.
3. Mental Age: mean absolute difference was three months.
4. Arithmetic Achievement: mean absolute difference was over four months.

While the time for arithmetic instruction was equated for the two classes, the class taught to solve problems using the "discovery method" was the arithmetic teacher's home room class, whereas the class taught to solve problems using the "rule method" was taught only arithmetic by this teacher. It was felt that this difference in teaching assignment did not influence the results of the study. A more satisfactory plan, however, would have been to have the arithmetic teacher teach arithmetic only to the two classes involved in the experiment. Due to administrative arrangements, however, this was not possible.

In summary, it was assumed that: (1) Stanford-Binet and W.I.S.C. intelligence scores were equivalent, (2) these test results were stable over a period of years, (3) the measuring instrument used did measure problem-solving ability, (4) two levels and two forms of the measuring instrument measured problem-solving progress equally well, and (5) modifying directions for administering a test did not seriously affect the reliability of difference scores obtained by comparing pre-test and post-test results.

VI. PLAN OF THE REPORT

The thesis report comprises five chapters. Chapter Two contains a review of selected research studies which attempted to compare the reasoning and problem-solving abilities of the retarded, the normal or average, and the gifted. Chapter Two also reviews recommendations made by authorities in the field of special education for teaching problem-solving to retarded subjects. Chapter Three describes the procedures of the present study. An analysis of the results of the study is contained in Chapter Four; and the conclusions and implications of the study, together with suggestions for future research, are found in Chapter Five.

CHAPTER II

REVIEW OF LITERATURE

Do the arithmetic problem-solving abilities of educable mentally retarded students differ from those of average or gifted students, and if so, in what ways? Selected research studies which attempted to answer this question were reviewed. These studies compared the arithmetic reasoning and problem-solving abilities of average, gifted and retarded subjects. The relevant findings of these selected studies are presented and discussed below. In addition, opinions of spokesmen in the field and statements of approved practices contained in curriculum guides used with E.M.R. students are presented.

The discussion of the relevant findings of the research studies selected for review follows a brief outline of the problem investigated and the procedures of each study.

1. STUDIES COMPARING ARITHMETIC REASONING AND PROBLEM SOLVING ABILITIES OF AVERAGE AND RETARDED CHILDREN

William Cruickshank compared the arithmetic ability of fifteen boys of normal intelligence with that of fifteen mentally retarded boys. The normal group and the retarded group were equated as to mental age and arithmetic achievement age. The mean chronological age of the retarded group was 14.29 years; for the normal group it was 9.09 years. The mean I.Q. of the retarded group was 73.33 while that of the normal group was 110.4. Cruickshank found that the arithmetic ability of the

two groups differed in several ways. The mentally retarded boys were inferior to the normal boys in the use of arithmetic vocabulary[1] as well as in work habits.[2] When both groups were required to solve arithmetic problems containing irrelevant information, the mentally retarded boys were found to be less capable of selecting the pertinent material needed to solve the problems.[3]

Another Cruickshank experiment consisted of two presentations of the same twenty problems. In the first presentation numerical values were excluded and the students were asked to identify the process used to solve the problems, while on the second presentation numerical values were included and the students were required to solve the problems by computation. The results indicated that the retarded boys, more so than the normal boys, tended to say that they would solve a problem using a certain process but used another process when actually working the problem.[4]

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[1] William M. Cruickshank, "Arithmetic Vocabulary of Mentally Retarded Boys," Journal of Exceptional Children 13: 65-69, December, 1946.

[2] William M. Cruickshank, "Arithmetic Work Habits of Mentally Retarded Boys," American Journal of Mental Deficiency 52: 318-330, April, 1948.

[3] William M. Cruickshank, "Arithmetic Ability of Mentally Retarded Children: Ability to Differentiate Extraneous Materials from Needed Arithmetical Facts," Journal of Educational Research 42: 161-170, November, 1948.

[4] William M. Cruickshank, "Arithmetic Ability of Mentally Retarded Children: Understanding Arithmetic Processes," Journal of Educational Research 42: 279-288, December, 1948.

Although Cruickshank's studies have often been cited by other writers[5] discussing the learning characteristics of the retarded, his conclusions were based on results obtained from a very small sample. Capobianco questioned the labelling of the normal group. He felt that Cruickshank's "normal" group, having a mean I.Q. of 110 and an I.Q. range of from 100 to 123, would not ordinarily be labelled as a normal but rather as an above average group.[6]

Capobianco analysed the arithmetic achievement of sixty-four retarded males.[7] The subjects were between ten and twenty-six years of age, had mental ages of over six years and I.Q.'s between forty and eighty. The Stanford Achievement Test of Arithmetic Reasoning Ability[8] was administered individually to all students. Questions were read to the subjects so that reasoning ability and not reading ability would be tested and each subject was given as much time as he needed to answer each question. Capobianco concluded that " ... the mentally handicapped groups studied approximate the normal group, according to the Stanford Achievement Test norms in arithmetic reasoning ability, when mental age is used as the criterion of expected performance level."[9] This would indicate that mentally retarded subjects and normal subjects of the same mental age are equal in arithmetic reasoning ability.

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[5] Karl C. Garrison, The Psychology of Exceptional Children (New York: The Ronald Press Co.,1950), pp.124-125; Samuel A. Kirk and G. Orville Johnson, Educating the Retarded Child (New York: Houghton Mifflin Co.,1951), pp.278-279; and Samuel A. Kirk and Oliver P. Kolstoe, "The Mentally Retarded," Review of Educational Research 23:p.409, December, 1953.

[6] Rudolph Capobianco, "Quantitative and Qualitative Analysis of Endogenous Boys and Exogenous Boys on Arithmetic Achievement," Studies of Reading and Arithmetic in Mentally Retarded Boys. Monographs of the Society for Research in Child Development 19: 1954,p.131.

[7] Ibid., 101-142.

[8] Stanford Achievement Tests, Harcourt, Brace and World, Inc, 750 Third Avenue, New York 17, New York.

[9] Capobianco, op.cit. p.128.

This finding is at variance with findings of Cruickshank who found the mentally retarded inferior to those of normal intelligence in almost every aspect of arithmetic reasoning and problem solving. Capobianco's findings might also be open to question as he compared actual achievement with expected achievement on a standardized test without adhering to standard procedure in administering the test. By varying the time allowed for the test and by reading the questions to the subjects, the "standardization" would be invalidated.

Burns asked the question, "How do retarded students differ from normal students in arithmetic ability?"[10] He discussed the findings of Cruickshank (previously reviewed), Costello, Engle and Hamtell,[12] and Gothberg,[13] and listed the following eight ways in which the mentally retarded differ from normal subjects in arithmetic ability:

1. They (the mentally retarded) are retarded in arithmetic vocabulary.
2. They are inferior in solving abstract and verbal problems.
3. They are better at concrete than abstract problem solving.
4. They have less understanding of processes needed in the solution of problems.

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[10] Paul C. Burns, "Arithmetic Fundamentals for the Educable Mentally Handicapped," American Journal of Mental Deficiency 65: 57-61, July,1961.

[11] Helen M. Costello, "The Responses of Mentally Retarded Children to Specialized Learning Experiences in Arithmetic" (unpublished doctoral Dissertation, the University of Pennsylvania, Phil., 1941).

[12] T. L. Engle and Iona C. Hamtell, "Comparison of Mental Defectives and Normal Children in Ability to Handle Clock and Calendar Situations," American Journal of Mental Deficiency 58: 655-658, April, 1954.

[13] L.C. Gothberg, "The Mentally Defective Child's Understanding of Time," American Journal of Mental Deficiency 53: 441-455, January,1949.

5. They (the mentally retarded) are more careless.
6. They are less successful than normal children in differentiating extraneous material.
7. They have little concept of sequence or time.
8. For mentally retarded children "readiness" is very important.

II. STUDIES COMPARING THE ARITHMETIC REASONING AND PROBLEM SOLVING ABILITIES OF THE NORMAL, GIFTED AND RETARDED

Feldhusen conducted a study comparing the efficiency of learning and retention among children of low, average and high intelligence.[14] He used three I.Q. groups with a mean chronological age of 112 months. Each I.Q. group consisted of twenty boys and twenty girls. The low group had W.I.S.C.[15] scores ranging from 55 to 80; the average group had scores ranging from 90 to 110; and the high group had scores of 120 and over. The learning tasks involved addition, counting and problem solving, all graded to the learner's achievement level.

Results of the study indicated no significant differences between the low, average and high I.Q. groups on the counting and addition tasks; but in learning a common problem-solving task in arithmetic,[16] the low I.Q. children took significantly longer. Mean

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[14] John Frederick Feldhusen, "A Study of Efficiency of Learning and Retention in Arithmetic Among Children of Low, Average and High Intelligence at a Mean Age of 112 Months," Dissertation Abstracts 19: 1651-1652, January, 1959.

[15] Wechsler Intelligence Scale for Children, published by the Psychological Corporation, 304 East 45 St., New York 17, New York, 1949.

[16] The common problem solving task consisted of dividing an unknown number of pennies among a given number of friends.

times for the three groups were 631 seconds for the low group, 235.2 seconds for the average group, and 237.8 seconds for the high group.

Using the same subjects, Klausmeier and Feldhusen tested for retention of arithmetic learning.[17] They found that retention was the same for children of low, average and high intelligence when the original task was graded to the learner's achievement level.

A later study conducted by Check[18] confirmed the findings of Klausmeier and Feldhusen. Using the same sample of forty retarded, forty average and forty bright children, he noted the time each subject took to make up a specified amount of money from a given collection of coins. The subjects were then divided randomly into retention and transfer groups. On the basis of relevant end-test and retention measures, Check concluded that retention was the same for children of low, average and high intelligence at a mean age of 127 months when the original task for each child was geared to his (or her) achievement level.

The above three studies sought to compare arithmetic abilities of retarded, average and gifted subjects when the learning tasks were geared to the learner's achievement level. The only significant difference among the groups was in the length of time taken to learn a problem-solving task. The retarded took longer to learn a problem-solving task than did the average or the gifted. This

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[17] Herbert J. Klausmeier and John F. Feldhusen, "Retention in Arithmetic Among Children of Low, Average and High Intelligence at 117 Months of Age," Journal of Educational Psychology 50: 88-92, April,1959.

[18] John Felix Check, "A Study of Retention of Arithmetic Learning With Children of Low, Average and High Intelligence at 127 Months of Age," Dissertation Abstracts 20: 955-956, September, 1959.

would seem to indicate that problem-solving methods suitable for bright and average students would be suitable for retarded students if the retarded students were given more time in which to complete a given task. This finding is at variance with the findings of Cruickshank who matched his subjects on the basis of mental age rather than chronological age as did Feldhusen, Klausmeier and Check.

A study which sought to determine intellectual patterns for retarded, average and gifted subjects was conducted by Gallagher and Lucito.[19] The investigators used the data of four studies, as well as the original standardization data of the W.I.S.C. for the seven to eleven age group, to make a total sample of ninety-three gifted children and thirty-eight gifted adults (125-145 I.Q.), 565 average children (90-110 I.Q.), and 202 retarded children and 172 retarded adults (40-75 I.Q.).

Mean-weighted W.I.S.C. subtest scores for each of the three I.Q. groups were ranked, and Spearman Rank Order correlations were calculated to draw comparisons. Internal consistency in intellectual patterns was evident within both the retarded and gifted groups. The correlations between gifted and retarded samples were consistently negative, and the conclusion drawn was that the patterns of intellectual development for the retarded and the gifted were, to some extent, mirror images of each other.[20]

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[19] James J. Gallagher and Leonard J. Lucito, "Intellectual Patterns of Gifted Compared with Average and Retarded," Exceptional Children 27: 479-482, May, 1961.

[20] Ibid., p.480.

The gifted, in Gallagher and Lucito's study, had high scores on subtests related to a "Verbal Comprehension" factor while the average and retarded appeared to be relatively weak on subtests related to this factor. The mentally retarded, however, seemed relatively strong on subtests relating to a "Perceptual Organization" or "Nonverbal Organization" or "Spatial-Perceptual Ability" factor while the gifted did relatively poorly on tests relating to this factor. Furthermore, Gallagher and Lucito found no similarity between the retarded children's patterns of intellectual development and those of children of average intelligence and a negative relationship between the patterns of gifted individuals and those of average abilities. These findings seem to suggest that different teaching methods should be used with different I.Q. groups.

Gallagher and Lucito criticised the findings of comparison studies which matched subjects on the basis of mental age scores. This, they felt, matched the subjects on the attributes being compared, such as memory, generalization ability and reasoning ability and accounted, in part, for the inconclusive results reported in many comparison studies.[21]

III. PROBLEM SOLVING IN ARITHMETIC AS IT APPLIES TO THE MENTALLY HANDICAPPED

In 1944, Johnson reviewed the literature dealing with problem-solving in arithmetic and summarized thirty-nine published reports of investigations on problem-solving.[22] He observed that Washbourne

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[21] Ibid., p.479.

[22] Harry C. Johnson, "Problem Solving in Arithmetic: A Review of the Literature," Elementary School Journal 44: 396-403, March, 1944, 476-482, April, 1944.

and Osborne had found problem-solving analysis of special value to children of inferior ability;[23] and that Monroe and Engelhart, using eighty-one matched pairs, concluded that children whose I.Q.'s were below 100 profited more from systematic instruction than did superior children.[24] Johnson concluded:

> A review of the studies reported here leaves room for doubt concerning the relative superiority that one method of solving problems may have over the others. It seems rather obvious that systematic and persistent training in any reasonable procedure for attacking problems is bound to result in improvement. There is evidence such training is especially effective in the case of children of less than average ability.[25]

Birch and Stevens, giving suggestions for teaching arithmetic to mentally-retarded youngsters also felt that systematic training in a reasonable procedure for attacking problems was necessary. They indicated that a commonly-accepted method was to read and re-read the problem, set down the key facts, set down what had to be found, perform the indicated operations and show that the question had been answered.[26]

Orville Johnson, writing on arithmetic education for the mentally handicapped, stated:

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[23] Carlton W. Washbourne and Raymond Osborne, "Solving Arithmetic Problems, "Elementary School Journal 27: 219-226, November, 1926, 296-304, December, 1926.

[24] Walter S. Monroe and Max Engelhart, "The Effectiveness of Systematic Instruction in Reading Verbal Problems in Arithmetic," Elementary School Journal 133: 377-381, January, 1933.

[25] Johnson, op.cit., p. 482.

[26] Jack W. Birch and Godfrey D. Stevens, Reaching the Mentally Retarded (Bloomington: Public School Publishing Co., 1955), p.38.

> While no experimental evidence, as far as the mentally handicapped are concerned, is available in regard to specific methodology, the most direct approach, requiring the least amount of abstraction and application of principles, is probably best.[27]

In discussing the merits of drill versus meaningful procedures in teaching arithmetic, the editors of the Canadian Research Digest felt that meaningful procedures tended to be superior for the pupil who was relatively high in ability and relatively low in achievement, while practice procedures were more effective with the pupil who had relatively low ability and relatively high achievement.[28]

IV. RESULTS OF LOCAL COMPARISON STUDIES WITH REGULAR STUDENTS

Vegreville Study

A study completed in the Vegreville School Division during the 1960, 1961 and 1962 school terms[29] compared the mathematics program as taught using the Seeing Through Arithmetic textbooks with the arithmetic program taught using the Study Arithmetic textbooks. The progress made by 95 grade two, 103 grade four, and 99 grade six students who had been divided into experimental and control groups was measured using the California Arithmetic Test. Gains over a six-month period indicated that the experimental group (using S.T.A. texts) made larger gains than did the control group. The report stated that on the basis of the findings of the study, the S.T.A. texts were adopted for use in the Vegreville School Division. Of particular interest to teachers of slow learners was the finding that the low grade six

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[27] Orville G. Johnson, "The Education of Mentally Handicapped Children," Education of Exceptional Children and Youth (Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1958), p.222.

[28] Canadian Research Digest 1, A publication of the Research Division, Canadian Education Association (Toronto: C.E.A., Spring, 1959), p. 54.

[29] H.P. Chomik, Mathematics Research Project, A report to the Divisional Board of the Vegreville School Division, no date.

group (each of the two groups at each grade level was further divided into low, average and high subgroups) in the classes using the S.T.A. texts made the most significant gains.

Calgary and Edmonton Study

A study conducted in 1962 by S. A. Lindstedt[30] compared students in Edmonton who had taken the S.T.A. program for three years with students in Calgary who had been taking the traditional arithmetic program. Seventy-five grade six students from Edmonton and the same number from Calgary made up the experimental and control groups respectively. The results of tests on Arithmetic Concepts and Problem Solving indicated, "... that the experimental group measured up to the control group even though the measuring instrument was designed for the traditional approach to problem solving."[31] Lindstedt also found that the experimental group could handle more abstract problems better than could the control group, and that they showed greater competence in solving more difficult problems with a familiar mathematical setting. These results indicate that the methods and procedures recommended in the S.T.A. texts are effective for regular class students. Whether or not these methods can be used effectively by educable mentally retarded is part of the question investigated in the present study.

V. SUMMARY

The contradictory findings of the studies reviewed indicated a certain lack of agreement as to the reasoning and problem-solving

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[30] S. A. Lindstedt, Changes in patterns of Thinking Produced By a Specific Problem Solving Approach in Elementary Arithmetic, University of Alberta, Calgary, 1963. (Typewritten report.)

[31] Ibid, p. 10.

abilities of the educable mentally retarded. While Cruickshank found the retarded to be inferior to average students,[32] Capobianco found the retarded group approximated the normal group in arithmetic ability when mental age was the criterion of expected performance level.[33]

Feldhusen,[34] Klausmeier and Feldhusen,[35] and Check[36] found little difference between the retarded, gifted and average or normal subjects in various arithmetic tasks, while Lucito and Gallagher[37] found the gifted to have intellectual patterns that were almost the mirror image of those of retarded subjects when W.I.S.C. subtest scores were compared.

Holt surveyed administrative practices concerning the educable mentally retarded in Canadian public schools and reported that teaching methods in classes for such students varied little from those in regular classes, except that more individual help was given and more time allowed.[38] He indicated a need for

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[32] The findings of Cruickshank are discussed on page 12 of this report.

[33] Capobianco, op.cit., p. 128.

[34] Feldhusen, op. cit., p. 1652.

[35] Klausmeier and Feldhusen, op. cit., pp.88-92.

[36] Check, op. cit., p. 956.

[37] Gallagher and Lucito, op. cit., pp. 479-482.

[38] P.W.R. Holt, "Administrative Practices Concerning the Educable Mentally Retarded in Selected Canadian Public Schools" (unpublished Master's Thesis, The University of Alberta, Edmonton, 1962), p. 121.

experimental research into the value of various methods of teaching.

The review of literature dealing with the problem-solving abilities of the educable mentally handicapped indicated agreement among researchers on the need for systematic instruction in problem-solving procedures. There were no indications, however, that any one method of solving problems was superior to any other method. The present study was undertaken to compare progress made by two classes taught to solve problems using two different methods, labelled the "rule method" and the "discovery method."

VI. RESEARCH HYPOTHESIS

In view of the inconclusive and contradictory research findings reported, the research hypothesis taken for the present study was the null hypothesis which is stated as follows: there is no difference, at the five per cent level of significance, in the mean gains in problem-solving ability of the two classes taught to solve problems in arithmetic by two methods, the "rule method" and the "discovery method" according to the measuring instruments used. These measuring instruments were:

1. The Arithmetic Reasoning portion of the _California Arithmetic Test_, elementary or upper primary level, Forms X and W.
2. The Arithmetic Problem Solving sections of the _Iowa Tests of Basic Skills_, grades three and five, Forms One and Two.

CHAPTER III

PROCEDURE OF THE STUDY

The present chapter outlines the procedure of the study, describes the nature of the population and the sample, and explains how the study was conducted.

1. POPULATION

Of the forty-one boys registered for placement in intermediate boys' opportunity classes at Queen's Avenue School for the 1961-62 school term, sufficient information for matching purposes was available for only thirty-nine. The raw data used for matching students are contained in Table A, Appendix A, while statistics calculated from this data are found in Table I following.

TABLE I

NATURE OF THE POPULATION OF EDUCABLE MENTALLY RETARDED BOYS CONSIDERED FOR MATCHING PURPOSES

Matching Criterion	Range of Scores	Mean	Median	Standard Deviation
Chronological Age (months)[1]	156-183	168.8	170	8.1
Intelligence Quotients[2]	47-91	69.8	72	10
Mental Age (months)[3]	81-142	114.7	120	15.9
Arithmetic Achievement(grade)[4]	2.9-7.6	5.04	5.0	11 months

2. MATCHING

Matching or pairing was completed prior to school opening in September, 1961, to avoid having to transfer pupils after they had been assigned to a class. Students were matched on the basis of chronological age, intelligence quotient, mental age and arithmetic achievement score. Good and Scates have stated:

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[1] This was the age of the students on September 1, 1961, correct to the nearest month.

[2] The intelligence scores were Stanford-Binet or W.I.S.C. scores.

[3] The mental age scores were corrected scores for subjects over thirteen years of age and obtained from tables included in the appendix of Lewis M. Terman and Maud A. Merril, _Measuring Intelligence, A Guide to the Administration of the New Revised Stanford-Binet Tests of Intelligence_ (Cambridge, Mass.: The Riverside Press, 1937), pp.415-450.

[4] These were scores obtained from the _California Arithmetic Tests_ administered in May of 1961.

> In educational experimentation, the characteristics that require consideration include intelligence, age, achievement in the particular field of experimentation, study habits, personality traits, physical conditions, sex and possibly race.[5]

Study habits, personality traits and physical conditions were not considered in matching the subjects as these factors were difficult to assess objectively from the information available in cumulative record cards. Observers of the classes, however, remarked on the similarities between partners. It seemed as if the matching process had also considered personality traits.

Originally the experimental classes were made up of fifteen pairs. However, a member of one pair withdrew from school, thus excluding his partner from the study (even though he remained in the class), and one pair[6] was excluded as both partners were so weak in arithmetic and so low in reading ability (they were both reading at a grade one level and working a low grade two level in arithmetic) that it was felt that they could not profit from the problem-solving instruction given the other members of the two classes.

Partners were assigned in random fashion to one or the other of the two experimental classes. A coin toss determined that the arithmetic teacher's homeroom class be taught to solve problems using the "discovery method" and, therefore, the other class was taught to solve problems using the "rule method."

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[5] Carter Good and Douglas E. Scates, Methods of Research (New York: Appleton Century-Crofts Inc., 1954), p.708.

[6] This pair consisted of students numbered 19 and 25 in Table A, Appendix A, and was the only pair having mental ages below ninety months.

TABLE II

THE NATURE OF THE CLASS TAUGHT TO SOLVE PROBLEMS USING THE "RULE METHOD"

Criterion (N= 13)	Range	Mean	Median	Standard Deviation
Chronological Age (mo.)	157-180	167.6	167	8.96
I.Q.	53-80	71.1	72	7.52
Mental Age (mo.)	91-132	116	117	13.1
Arithmetic Achievement (grade score)	3.6-6.9	5.2	5.1	9.9 months

TABLE III

THE NATURE OF THE CLASS TAUGHT TO SOLVE PROBLEMS USING THE "DISCOVERY METHOD"

Criterion (N = 13)	Range	Mean	Median	Standard Deviation
Chronological Age (mo.)	158-183	167.3	168	7.33
I.Q.	56-82	71.5	76	8.03
Mental Age (mo.)	93-137	116.7	121	13.2
Arithmetic Achievement (grade scores)	3.4-6.6	5.05	5.0	8 months

3. TESTING

The California Arithmetic Test[7]

The Arithmetic Reasoning portion of the California Arithmetic Test, Form X, elementary level, was administered to all students in the two experimental classes who had achieved a grade score of 4.4 or higher on the California Arithmetic Test administered in May, 1961. Those students who had scored below grade 4.4 were given the upper primary level of the C.A.T., Form X. These tests were administered during the morning of Tuesday, September 26, 1961, according to the directions given in the manuals.[8,9]

During the morning of Wednesday, May 23, 1962, Form W of the Arithmetic Reasoning portion of the C.A.T., elementary or upper primary level, was administered to all students in the two experimental classes in order that problem-solving progress and arithmetic reasoning progress during the eight-month study might be measured and compared.

The Arithmetic Reasoning portion of the C.A.T.was chosen to measure problem-solving ability and to compare the progress in problem-solving ability made by the two experimental classes because:

1. The students were familiar with the format of the C.A.T., having taken one form of the test at least in May, 1961.

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[7] The California Arithmetic Test, (C.A.T.) published by the California Test Bureau - 5916 Hollywood Boulevard, Los Angeles 28, California, 1957.

[8] Ernest W. Tiegs and Willis W. Clark, Manual, California Achievement Tests, Upper Primary, Forms W & X (Los Angeles: California Test Bureau, 1957).

[9] As above, but Elementary instead of upper primary.

2. Each May all Edmonton opportunity class students are given the California Achievement Tests (Complete Battery), which contain the arithmetic test. Therefore, the post-test was a part of the regular May testing program.

3. The C.A.T. test contains a large number of items which measure arithmetic reasoning ability. The elementary level test contains 45 items (15 of which are problems) while the upper primary level test contains 40 items (of which 10 are problems).

4. Two equivalent forms, Form X and Form W, of the California Arithmetic Test were readily available.

The Iowa Tests of Basic Skills[10]

To check or confirm the results obtained from the C.A.T., the grades three and five problem solving tests contained in the Iowa Tests of Basic Skills, Form 1, were administered to all members of the two experimental classes on Tuesday and Wednesday, October 3 and 4, 1961. On May 25 and 28, 1962, the grades three and five problem solving tests contained in Form 2 were administered.

The problems in the Iowa problem-solving test are arranged in ascending order of difficulty, and tests for successive grades overlap. Questions one to twenty-five inclusive comprise the grade three test while the grade five test begins with question twenty-six and ends with question fifty-four, with the grade four test beginning with question thirteen and ending with question thirty-eight.

In order that reading ability (or lack of it) might not influence the grade score obtained on the Iowa test, the questions

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[10] Iowa Tests of Basic Skills, Form 1 and 2, published by Houghton Mifflin Company, 2 Park Street, Boston, Mass., 1956.

were read to the pupils before the test began and difficult words were pronounced for the students during the test. To eliminate the effects of lucky guesswork, students were required to work the problems and record their solution to the problem rather than pick one of four possible solutions. As this would take extra time, the time limits for the test were extended by five minutes to thirty-five minutes.

4. CONTROLS

In planning the present study, an attempt was made to consider the many factors that might be involved and needed to be controlled so that the effects of the two problem-solving methods could be tested for significance.

Matching

Students were matched as closely as possible considering the limited size of the population from which the sample could be chosen. The two classes seemed comparable on the criteria considered for matching (see Table II and Table III, page 27).

Arithmetic Content

The content of the arithmetic program was the same for both groups. Both classes used the same series of arithmetic texts and the problems presented for solution were identical for both groups.

Arithmetic Texts. Students of both classes used *Winston Arithmetics*[11] textbooks for the arithmetic program. As the total student arithmetic achievement level varied from grade 3.4 to grade 6.9, texts of all levels from grade three to grade six inclusive were used, with each student working in a text suited to his particular level of achievement.

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[11] H. L. Stein, J. W. Gilles, E. Hodgson and A.F. Deverall (eds.) *Winston Arithmetics* (Toronto: The John C.Winston Co. Ltd., 1954), *Discovering Numbers*, *Learning Numbers*, *Exploring Numbers* and *Understanding Numbers*.

Problem Sheets. Teacher-made problem sheets, each containing eight problems arranged in ascending order of difficulty from a grade three level to a grade six level were used with the two classes.[12]

These problems were gathered from various sources to introduce as much variety as possible into the types of problems presented for solutions. Twenty-five problem-solving sheets were used during the year. At the beginning of each week the problem sheets were introduced and the problems read. The problems were discussed and the students were taught to solve the problems according to the problem-solving procedures outlined for the two experimental classes. The problem sheets were collected by the teacher at the end of each arithmetic period, and students were not allowed to take the problem sheets home or work on them at any time other than during the arithmetic periods.

Time

Two time factors were considered. The time of day for arithmetic instruction was the same for both classes to prevent systematic differences which might occur if one class met early in the day for arithmetic instruction and the other late in the day. The other factor was the amount of time spent by each class solving the problems contained in the problem sheets.

Time for arithmetic instruction. The time for arithmetic instruction was equated for the two classes. Each class had two 9:30 to 10:20 and two 10:50 to 11:40 arithmetic periods each week.

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[12] These problem sheets are contained in Appendix B.

Time for solving problems. Approximately one hour each week, fifteen minutes each arithmetic period, was devoted to teaching the problem solving procedures, the "rule method" and the "discovery method," to the two experimental classes. However, two things made it difficult to equate the time spent with the two classes in solving the problems contained in the problem sheets. To begin with, students worked at different rates of speed; and, while some students would complete the problem sheets quickly and proceed to work in their arithmetic textbooks, others would require additional time and help to finish working the problems before the end of the period. Secondly, as students varied greatly in ability, some could solve all of the problems while others would be able to complete as few as two of the eight problems with any degree of understanding or competence. These students were not encouraged to attempt problems too difficult for them, but neither were they discouraged from attempting any problems they felt they could solve. It was felt by the arithmetic teacher that the time spent solving the problems contained in the problem sheets was roughly the same for the two classes. However, the time element could not be closely controlled due to the aforementioned reasons. Also, the imposition of rigid time limits would limit, in many cases, spontaneous discussion arising from the problems. Such a procedure might force or hurry students along without giving them time or opportunity to synthesize their thoughts or express their ideas.

Physical Environment

Both experimental classes received their arithmetic instruction in the same classroom, this being the home room of the class taught the "discovery method" of solving problems. The class taught to solve problems by the "rule method" used this classroom only during the arithmetic periods.

Motivation

Every attempt was made during the course of the study to treat the two classes alike, to develop equal interest in their respective problem-solving procedures, and to keep the incentives to learning equal for the two classes.

Instruction. One teacher taught arithmetic to both classes. He had no reason to believe that one problem-solving procedure was in any way superior to the other and he attempted at all times to present the two procedures with equal enthusiasm. Students worked in a relaxed classroom atmosphere and were encouraged to express their opinions freely and ask questions whenever they wanted additional information, help, or clarification of difficult material.

Incentives. After the problem sheets had been marked, they were returned to the students and the questions reviewed. Students were encouraged to improve their own marks and compete with themselves. In addition, they were encouraged to compare their marks with those of their classmates; a resultant keen competition was evident within each class. At no time during the study did the arithmetic teacher indicate to either class that the classes were being compared or that gains made by the two classes were to be compared.

Students taught to solve problems using the "rule method" were given one mark for underlining the part of each problem which asked the question, one mark for indicating the correct process or processes to use in solving the problem, one mark for performing the correct computation, and one mark for having the correct answer to the problem.

The students taught to solve problems using the "discovery method" received a maximum of three marks for translating the problem into a mathematical sentence or equation, and one mark for indicating the correct answer.

5. SUPERVISION OF THE STUDY

To provide a check on the methods of instruction and to ensure that testing conditions were the same for both classes, several persons assisted in the supervision of the study.

Testing

Mr. P.W.R. Holt, principal of Queen's Avenue School, assisted in administering the tests at the beginning and at the conclusion of the study.

Observers

On January 25, 1962, the members of the thesis committee observed the experimental classes being taught problem-solving. On February 6, 1962, Dr. K. Grierson, School Psychologist in charge of Special Education in the Edmonton Public Schools, also observed the two classes. In addition to the above observers, the school principal observed the classes at various times during the term of the experiment.

All of the observers were satisfied that the problem-solving procedures taught the two groups of educable mentally retarded students were not the same and were consistent with the methods as outlined for the two experimental classes. They also felt that the enthusiasm and response of the two classes were comparable.

CHAPTER IV

ANALYSIS OF RESULTS

The present chapter contains pre-test and post-test results, an analysis of the test results using a nonparametric test, observations on the data collected, and an analysis of test results using a parametric test, the t-test.

1. TEST RESULTS

The scores obtained by each subject on the tests administered in September and May, the gains made by each subject during the eight-month study, and the differences between the gains are contained in Tables IV, V, VI and VII. Table IV contains the results of the Arithmetic Reasoning portion of the *C.A.T.*, Forms X and W, while Table V considers the number of problems correctly solved on the problem-test section of the Arithmetic Reasoning Test. Tables VI and VII contain the grade placement results of the grades three and five problem-solving sections of the *Iowa Tests of Basic Skills*, Forms 1 and 2.

The standard deviation for each column was found by applying the following usual formula for ungrouped data:

$$\text{S.D.} = \left[\frac{\Sigma x^2}{N} - \left(\frac{\Sigma x}{N} \right)^2 \right]^{\frac{1}{2}}$$

S.D. = standard deviation
N = number of cases
Σx = sum of the numerical values of observation
Σx^2 = sum of the squares of the observations

TABLE IV

GRADE PLACEMENT SCORES, GAINS, AND DIFFERENCES BETWEEN GAINS ON THE ARITHMETIC REASONING PORTION OF THE C.A.T., FORMS X AND W, FOR "DISCOVERY METHOD" AND "RULE METHOD" GROUPS

Pair No. N=13	Rule Method Class			Discovery Method Class			Difference in Gains A - B
	Form X Sept.	Form W May	Gain A	Form X Sept.	Form W May	Gain B	
1	8.1	9.0	9 mo.	5.7	6.5	8 mo.	1 month
2	5.1	5.3	2 "	6.1	7.1	10 "	-8 "
3	4.7	7.7	30 "	5.5	6.3	8 "	22 "
4	5.9	6.5	6 "	6.1	5.9	-2 "	8 "
5	3.4	3.8	4 "	2.9	4.0	11 "	-7 "
6	6.5	6.7	2 "	5.1	6.5	14 "	-12 "
7	4.4	5.9	15 "	5.3	6.3	10 "	5 "
8	3.3	4.0	7 "	5.3	6.9	16 "	-9 "
9	5.2	4.3	-9 "	2.3	3.6	13 "	-22 "
10	4.8	5.1	3 "	4.8	6.1	13 "	-10 "
11	4.7	6.1	14	2.7	3.5	8 "	6 "
12	6.3	7.1	8	6.7	7.4	7 "	1 "
13	2.9	3.8	9	2.9	3.5	6 "	3 "
Total	66.2	76.2	100	61.4	73.6	122	-22
Mean	5.09	5.86	7.7	4.72	5.66	9.4	-1.7
S.D.	1.49	1.52	[illegible]	1.43	1.40	4.4	10.75 mo.

TABLE V

NUMBER OF PROBLEMS CORRECTLY SOLVED, GAINS, AND DIFFERENCES BETWEEN GAINS FOR PROBLEMS CONTAINED IN ARITHMETIC REASONING PORTION OF THE C.A.T. FORMS X AND W, FOR "RULE" AND "DISCOVERY" GROUPS

Pair No. N=13	Rule Method Class			Discovery Method Class			Difference in Gains A - B
	Form X Sept.	Form W May	Gain A	Form X Sept.	Form W May	Gain B	
1	10	12	2	5	5	0	2
2	8	7	-1	8	9	1	-2
3	5	8	3	6	7	1	2
4	6	7	1	7	6	-1	2
5	4	3	-1	2	5	3	-4
6	8	9	1	2	8	6	-5
7	3	6	3	3	8	5	-2
8	3	6	3	4	5	1	2
9	7	2	-5	4	5	1	-6
10	5	5	0	2	4	2	-2
11	8	5	-3	2	4	2	-5
12	9	10	1	9	12	3	-2
13	3	5	2	1	4	3	-1
TOTAL	79	85	6	55	82	27	-21
MEAN	6.08	6.54	.46	4.23	6.31	2.1	-1.64
S.D.	2.1	2.7	2.34	2.5	2.3	1.86	2.8

TABLE VI

GRADE PLACEMENT SCORES, GAINS, AND DIFFERENCES BETWEEN GAINS ON THE GRADE THREE PROBLEM SOLVING SECTION OF THE IOWA TESTS OF BASIC SKILLS, FORMS 1 AND 2, FOR "RULE METHOD" AND "DISCOVERY METHOD" GROUPS

Pair No. N=13	Rule Method Group			Discovery Method Group			Difference in Gains
	Form 1 Sept.	Form 2 May	Gain A	Form 1 Sept.	Form 2 May	Gain B	A - B
1	5.4*	5.4*	0 mo.	4.1	5.1	10 mo.	-10 mo.
2	4.6	5.2	6	5.0	5.1	1	5
3	4.4	4.9	5	4.7	5.0	3	2
4	5.0	5.1	1	3.7	3.9	2	-1
5	2.9	3.0	1	2.9	3.8	9	-8
6	4.3	5.2	9	4.6	5.1	5	4
7	4.3	5.2	9	5.0	4.9	-1	10
8	2.9	3.0	1	3.8	4.9	11	-10
9	3.4	3.1	-3	3.0	3.9	9	-12
10	5.2	4.7	-5	3.2	4.7	15	-20
11	3.8	4.4	6	4.1	4.4	3	3
12	5.0	5.2	2	5.0	5.1	1	1
13	3.3	3.0	-3	2.7	3.3	6	-9
TOTAL	54.5	57.4	29 mo.	51.8	59.2	74 mo.	-45
MEAN	4.19	4.41	2.2	3.98	4.55	5.7	-3.5
S.D.	.829	.959	4.3	.81	.6	4.58	8.11

* Maximum grade placement score possible with all problems correct.

TABLE VII

GRADE PLACEMENT SCORES, GAINS, AND DIFFERENCES BETWEEN GAINS ON THE GRADE FIVE PROBLEM SOLVING SECTION OF THE IOWA TESTS OF BASIC SKILLS, FORMS 1 AND 2, FOR THE "RULE METHOD" AND "DISCOVERY METHOD" GROUPS

Pair No. N =11	Rule Method Class			Discovery Method Class			Difference in Gains A - B
	Form 1 Sept.	Form 2 May	Gain A	Form 1 Sept.	Form 2 May	Gain B	
1	8.0	8.9	9 mo.	4.8	5.6	8 mo.	1
2	5.3	7.3	20	5.6	6.3	7	13
3	5.3	5.5	2	5.2	5.9	7	-5
4	5.2	4.1	-11	5.0	5.4	4	-15
5	......................Not Tested............................						
6	6.0	6.1	1	5.3	5.2	-1	2
7	5.5	5.8	3	5.7	6.1	4	-1
8	3.1	3.6	5	3.3	5.6	23	-18
9	3.6	4.3	7	3.1	3.3	2	5
10	5.5	4.6	-9	4.1	4.6	5	-14
11	4.8	5.2	4	3.8	3.8	0	4
12	5.7	5.5	-2	6.4	7.3	9	-11
13	......................Not Tested............................						
TOTAL	58.0	60.9	29 mo.	52.3	59.1	68 mo.	-39
MEAN	5.273	5.537	2.6	4.75	5.37	6.2	-3.6
S.D.	1.21	1.45	8.06	1.00	1.09	6.13	9.38

2. NONPARAMETRIC ANALYSIS OF RESULTS

Nonparametric tests do not assume that scores under analysis are drawn from a population distributed in a certain way, e.g., from a normally-distributed population. These tests also have certain computational advantages and some are particularly suited to testing results obtained from small samples.[1] As noted previously, in Chapter One, the present samples were small and drawn from a population which could not be considered as being normally distributed. Therefore, a nonparametric test was chosen to measure the differences between the gains made by the two experimental classes to determine if statistically significant differences existed; or, to state this in another way, to determine if the mean difference between the gains made by the two classes was equal to zero or significantly different from zero.

Research Hypothesis

The research hypothesis to be tested is stated as follows: (H_o) there is no difference between the mean gains in problem-solving ability of the two experimental classes; or, stated in another way, the mean difference between gains made by the two groups is zero. The alternate hypothesis (H_1) is as follows: there is a difference between the mean gains, or, stated another way, the mean difference between gains made by the two experimental classes is not zero.

Statistical Test

The Walsh nonparametric test[2] requires that measurements

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[1] Sidney Siegel, Nonparametric Statistics for the Behavioural Sciences (Toronto: McGraw-Hill Book Co. Ltd., 1956)p.vii.

[2] Siegel, op.cit., pp.83-87.

to be compared must be in at least an interval scale. The measurements must also be drawn from a symmetrical population, a population where the mean is an accurate representation of central tendency and is equal to the median. As the numerical differences between gains could be considered to be in an interval scale and as the assumption seemed tenable that the observed differences came from a symmetrical population of differences, the Walsh test was chosen to analyse the results of the present study.

Significance Level

The usual significance level of $\alpha = .05$ was chosen, using a two-tailed test, because the direction of any observed difference between gains was not hypothesized.

Rejection Region

The null hypothesis (H_0) would be rejected in favor of the alternate hypothesis (H_1) if any values given in Table C (Appendix C) opposite the .047 level of significance for N = 13, and opposite the .056 level of significance for N = 11, were observed.

When N = 13 pairs, a two-tailed test allows the rejection of H_0 at the .047 level of significance if:

1. Max. $\left[\frac{1}{2}(d5 + d13) \text{ or } \frac{1}{2}(d6 + d12)\right]$ is less than 0.

or

2. Min. $\left[\frac{1}{2}(d1 + d9) \text{ or } \frac{1}{2}(d2 + d8)\right]$ is greater than 0.

The above can be interpreted somewhat as follows: If the maximum value of either $\frac{1}{2}(d5 + d13)$ or $\frac{1}{2}(d6 + d12)$ is less than zero, or if the minimum value of either $\frac{1}{2}(d1 + d9)$ or $\frac{1}{2}(d2 + d8)$

is greater than zero, the null hypothesis may be rejected at the .047 level of significance.

Procedure

The difference scores were obtained by subtracting the gain made by the "discovery method" partner from the gain made by the "rule method" partner on each of the four measures tested (see Tables IV, V, VI, and VII). The difference scores were arranged in Table VIII in order of increasing size, taking into account the sign of each difference. The smallest difference is d1 and the largest is d13, except for the Iowa grade five test where the largest difference is d11. Thus the smallest difference, d1, in the first column of Table VIII represents a difference in gain of twenty-two months favoring the "discovery method" partner, while d13, the largest gain represents a difference in gain of twenty-two months favoring the "rule method" partner.

The analysis of the differences between gains using the Walsh nonparametric test did not allow the rejection of the null hypothesis (H_0) for any of the measures analysed. (See Appendix C). No significant differences between means were found.

Using a two-tailed parametric t-test (see Appendix D) no significant difference between the mean gains of the two groups was observed. While it was felt that the data of the present study was more suited to analysis using nonparametric statistical tests, curiosity on the part of the researcher prompted an analysis of the differences between gains using the t-test.

TABLE VIII

DIFFERENCES BETWEEN GAINS WITH SIGNED DIFFERENCES ARRANGED IN ORDER OF INCREASING SIZE

	California Arithmetic Test		Iowa Tests of Basic Skills	
	Arithmetic Reasoning (months) N = 13	No. of Problems Correct N = 13	Grade Three (months) N = 13	Grade Five (months) N = 11
d1	-22	-6	-20	-18
d2	-12	-5	-12	-15
d3	-10	-5	-10	-14
d4	- 9	-4	-10	-11
d5	- 8	-2	- 9	- 5
d6	- 7	-2	- 8	- 1
d7	1	-2	- 7	1
d8	1	-2	1	2
d9	3	-1	2	4
d10	5	2	3	5
d11	6	2	4	13
d12	8	2	5	
d13	22	2	10	

3. OBSERVATIONS

Gains of the Two Educable Mentally Retarded Classes on the Arithmetic Reasoning Portion of the C.A.T.

During the eight-month study, the mean gains of the "discovery method"and "rule method" groups were 9.4 months and 7.7 months, respectively. These approximate the gains made by average students. The mean gain of the combined group (8.5 months) is slightly in excess of the gain expected of average students during an eight-month period.

A Comparison of C.A.T. and Iowa Test Results

Direction of Mean Differences. While no statistically significant differences between mean gains were observed, all the

observed differences favored the "discovery method" group.

Difference in Magnitude of Gains. The gains observed on the C.A.T. were larger than the gains observed on the Iowa problem solving tests. This finding may have been due partly to the nature of the two tests and partly to the modification of instruction for administering the Iowa Test.[3]

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[3] These modifications are outlined on page 8 of Chapter One and discussed further in Chapter Three, page 30 .

CHAPTER V

CONCLUSIONS, IMPLICATIONS AND SUGGESTIONS FOR FURTHER RESEARCH

The present study attempted to answer the following questions:

1. Are two problem-solving methods, a "rule method" and a "discovery method" equally effective in increasing the problem-solving abilities of educable mentally retarded students of secondary school age?
2. Can E.M.R. students profit from the methodology recommended in arithmetic textbooks which emphasize the "new" mathematics?

Two matched groups of educable mentally retarded boys were taught to solve problems in arithmetic using two different procedures. Gains in problem-solving ability over an eight-month experimental period were measured by means of pre and post-tests. The mean gains made by the two groups on the following measures were compared.

1. The Arithmetic Reasoning portion of the *California Arithmetic Achievement Test* (*C.A.T.*).
2. The number of problems correctly solved in the Arithmetic Reasoning portion of the *C.A.T.*
3. The grade three Arithmetic Problem Solving section of the *Iowa Tests of Basic Skills*.
4. The grade five Arithmetic Problem Solving section of the *Iowa Tests of Basic Skills*.

The difference between mean gains made by the two groups was tested for significance using a nonparametric statistical test,

the Walsh test. A further analysis of the data, using a parametric t-test, was also made.

1. CONCLUSIONS

The conclusions of the study are discussed below under three headings which discuss the size of the gains made, the statistical significance of the observed differences in the mean gains, and the direction of the observed differences.

Size of Observed Gains

The eight-month study resulted in mean gains of 9.4 months and 7.7 months for the "discovery method" and "rule method" groups respectively on the Arithmetic Reasoning portion of the C.A.T. The mean gain of the combined group, 8.5 months, was obviously highly satisfactory for educable mentally retarded students and indicated that the two problem-solving procedures which were taught were effective in increasing the problem-solving ability of the E.M.R. boys taking part in the study.

The mean gains obtained on the Iowa problem tests were smaller than those obtained on the C.A.T. This may have been due, in part, to the very nature of the Iowa tests and to the way in which the tests were given, as the directions for administering the tests were modified.[1]

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[1] The modifications required for the administering of the Iowa Tests of Basic Skills were described in Chapter One (p. 8) and Three(p. 30).

Significance of Differences Between Mean Gains

Using a two-tailed test,[2] no significant differences ($\alpha = .05$) were found between the mean gains of the two groups on any of the four measures compared. The original hypothesis of no difference between mean gains was, therefore, supported. On the basis of this analysis the two problem-solving procedures could be considered as being equally effective for the E.M.R. boys participating in the study.

This finding supports the conclusions of Johnson, Birch and Stevens, and Johnson[3] (cited in Chapter Two) who noted that systematic and persistent training in any reasonable problem-solving procedure would result in improvement, but that little evidence was available to support the belief that any one procedure was superior for use with E.M.R. students.

Direction of Observed Differences in Mean Gains

The observed differences in the mean gains of the two experimental groups favored the group taught to solve problems using the "discovery method". As indicated in Table IX, the differences between the mean gains of the two groups appear to

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[2] As the literature did not clearly indicate the superiority of any one problem-solving procedure, and as the teacher conducting the study had no pre-conceived notions regarding the relative effectiveness of the two problem-solving methods, a two-tailed test of significance was indicated. Such a test is applicable when the direction of observed differences (if any) cannot be predicted in advance.

[3] Harry C. Johnson, "Problem Solving in Arithmetic: A Review of the Literature," Elementary School Journal 44: 396-403, March, 1944, 476-482, April, 1944; Jack W. Birch and Godfrey D. Stevens, Reaching the Mentally Retarded (Bloomington: Public School Publishing Company, 1955), p. 38; Orville G. Johnson, "The Education of Mentally Handicapped Children," Education of Exceptional Children and Youth, (Englewood Cliffs, N. J.: Prentice-Hall, Inc., 1958) p.222.

be quite substantial, even though they are not significantly different statistically.

TABLE IX

MEAN GAINS AND DIFFERENCES BETWEEN MEAN GAINS OF THE TWO EXPERIMENTAL CLASSES ON FOUR TEST MEASURES

Test Measure	Discovery Method Mean Gain	Rule Method Mean Gain	Difference (favoring the "discovery method")
ARITHMETIC REASONING portion of C.A.T.	9.4 months	7.7 months	1.7 months
Number of problems correct on C.A.T.	2.10 problems	.46 problems	1.64 problems
Iowa Problem Test Grade Three	5.7 months	2.2 months	3.5 months
Iowa Problem Test Grade Five	6.2 months	2.6 months	3.6 months

2. IMPLICATIONS

The three main findings are:

(a) that both groups scored adequate gains,

(b) that the differences between the groups were not statistically significant, and

(c) that the observed differences favored the group taught a "discovery method" of solving problems.

The implications of these findings are discussed below.

Both Experimental Groups Scored Adequate Gains.

As both experimental groups of E.M.R. boys scored gains on the C.A.T. which approximated the gains expected of average

students, the two problem-solving procedures were considered effective in increasing the reasoning ability of E.M.R. students. It is, therefore, probable that systematic, intensive and consistent instruction in any reasonable, structured problem-solving procedure would prove effective in increasing the arithmetic reasoning ability of E.M.R. students. If this is so, the teacher should choose to teach the problem-solving procedure he or she feels would be most effective for the particular group of E.M.R. students being taught.

As the E.M.R. student is given much individual help, based on his particular needs, it should not be inferred from the present findings that any one method of solving problems, or any one problem-solving approach would best meet the needs of all students.

The problem-solving procedures taught were based on methods recommended in elementary arithmetic textbooks in use in 1961. The findings of the present study would, therefore, suggest that E.MR. students can benefit from the same type of instruction in arithmetic that is given to average students. This supports the findings of Feldhusen, Klausmeier and Feldhusen, and Check (cited in Chapter Two),[4] who found little difference between the arithmetic abilities of average, gifted and retarded students when the learning tasks were geared to the learner's achievement level. On the other hand, Gallagher and Lucito,[5] as

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[4] These findings are summarized on page 16, Chapter Two.

[5] James J. Gallagher and Leonard J. Lucito, "Intellectual Patterns of Gifted Compared with Average and Retarded," Exceptional Children 27: 479-482, May, 1961 and cited in Chapter Two, p. 18.

previously noted, found little or no similarity between the patterns of intellectual development of average and retarded students, and noted a negative relationship between the patterns of the gifted and the retarded. While the patterns of intellectual development of the retarded cannot be inferred from the present study, the results did imply that problem-solving procedures recommended for average students could be used successfully by educable mentally retarded students.

No Statistically Significant Differences Were Found Between the Gains Scored by the Two Groups

The use of two-tailed tests of significance failed to indicate any significant differences between mean gains. Using the nonparametric Walsh test, a one-tailed test would have given the same results; but had a one-tailed parametric test, such as the t-test, been applicable, statistically significant results would have been obtained on at least two of the four measures compared. This indicates that if the direction of any differences in gains could be predicted (in order that a one-tailed test of significance could be used) and if the sample size could be increased, significant differences could be obtained. A future study into the relative effectiveness of different problem-solving procedures could well be designed to test the hypothesis that one problem-solving procedure is superior to another.

Observed Differences Favored the Group Taught to Solve Problems Using a "Discovery Method"

The group taught to use a "discovery method" to solve problems scored larger mean gains than did the group taught to use a "rule method" on all four compared measures. The "discovery

method" was an adaptation of procedures recommended in Seeing Through Arithmetic[6] (S.T.A.) textbooks, which are replacing earlier texts, such as the Study Arithmetic[7] texts. Reports of local comparison studies, such as the Vegreville[8] and the Lindstedt[9] studies, (cited in Chapter II), also indicate that the methods recommended in the S.T.A. texts compare favorably with the more traditional approaches. For example, the Vegreville study states in part:

> .... it is interesting to note that the Low Group in the experimental class made the most significant gain. It is also interesting to note that the total gain recorded by the experimental group is more than double the gain recorded by the control group.[10]

The "experimental group" used the S.T.A. methods, while the "control group" used the more traditional approach. Lindstedt also found that students using S.T.A. methods were superior in ability to solve abstract problems to students using a more traditional approach, and felt the equation approach gave the elementary grade pupil a technique which enabled him ".... to solve problems with the sophistication of a true mathematician."[11]

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[6] M.L. Hartung, H. Van Engen, L. Knowlen, R. A. Rennie, Seeing Through Arithmetic, The Seeing Through Arithmetic Series (Toronto: W. J. Gage and Company).

[7] J. W. Studebaker, W. C. Findley, F. B. Knight, G. M. Ruch, Study Arithmetic, The Study Arithmetic Series (Toronto: W. J. Gage and Company).

[8] H. P. Chomik, Mathematics Research Project, unpublished report to the Divisional Board of the Vegreville School Division, no date.

[9] S. A. Lindstedt, Changes in Patterns of Thinking Produced by a Specific Problem Solving Approach in Elementary Arithmetic, unpublished report, fall 1962.

[10] H. P. Chomik, op. cit., p.7.

[11] S. A. Lindstedt, op. cit., p. 12.

These studies indicated that the methods and procedures recommended in the S.T.A. texts were effective for average students in regular classes. The results of the present study imply that educable mentally retarded students were not harmed by using methods adapted from those recommended in the new arithmetic texts.

3. SUGGESTIONS FOR FURTHER RESEARCH

Of prime importance is the need for developing measuring instruments which measure more precisely the abilities of educable mentally retarded subjects. Relying on test measures designed for average students and using grade placement scores intended for average students is unrealistic. In the present study, various assumptions had to be made concerning the tests used to measure progress in arithmetic problem-solving. A test especially designed to measure the problem-solving abilities of E.M.R. students would have proven invaluable in comparing the relative effectiveness of the two problem-solving procedures. Such a test would be even more useful if, in addition to measuring the problem-solving abilities of E.M.R. students, it had norms applicable to average as well as retarded students. This would allow more meaningful comparisons to be made between the abilities of average and retarded students. This would provide information and knowledge useful in developing more effective programs of instruction for the educable mentally retarded.

Researchers encounter difficulties when attempting to study the mentally retarded.

1. The number of E.M.R. in any given school system is relatively small. It is, therefore, difficult to secure samples sufficiently large to test statistically without including several widely-separated centres or districts. To further complicate matters, the districts may vary greatly in cultural and socio-economic aspects, and so present confounding variables.

2. The range of abilities in a given sample is often so large that no single test measure can be used with all members of the sample. When different levels of one test are used, the reliability between levels, as well as the reliability of the test itself, must be considered. Observed results may have to be unrealistically large before they can be considered statistically significant.

3. Educable mentally retarded students progress more slowly than average students and experiments are often of short duration.

For these reasons, it is quite possible to obtain results which are adequate for E.M.R. students but not statistically significant.

Rather than allow these and other difficulties to limit research in the area of mental retardation, increased use of another approach should be encouraged. If numerous small samples, even individual students, could be observed and studied over an extended period of time, and results of these studies combined, a more complete picture of the abilities and learning patterns of the educable mentally retarded would emerge. This would prove invaluable in assessing the cumulative effects of continuous developmental programs and in formulating hypotheses regarding the characteristics of mental retardation.

The difficulty of obtaining sufficient research personnel to conduct the many long-term studies recommended could be partly alleviated by increased involvement of the classroom teacher. The teacher is in an ideal position to observe students and record observations and should be encouraged to assist in more research studies. A greater volume of research would be possible, resulting in the gathering of more evidence concerning the abilities of the E.M.R.

Undoubtedly, the teacher who is a producer of research is a better consumer of research. He learns what he must to understand and evaluate reports of research studies; he gains an increased awareness of the role of research in improving methods of instruction.

In summary, the recommendations for further research indicate a need for (1) developing a test measure to measure more precisely the problem-solving abilities of the educable mentally retarded, (2) studies which concentrate on fewer students, but are of much longer duration than many present studies, and (3) increased involvement of the teacher in classroom research.

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APPENDIX "A"

RAW DATA USED FOR MATCHING

MATCHED PAIRS

TABLE A

CHRONOLOGICAL AGES, I.Q'S, MENTAL AGES, AND ARITHMETIC ACHIEVEMENT SCORES OF BOYS COMPRISING THE POPULATION OF THE PRESENT STUDY

Student N=39	Chronological Age (months)	Intelligence Quotient	Mental Age (mos.)	Arithmetic Achievement
1.	156	91	142	4.8
2.	157	62	97	3.9
3.	158	77	121	3.4
4.	158	79	124	5.1
5.	159	69	109	4.1
6.	159	76	120	5.0
7.	159	80	126	5.0
8.	160	76	121	5.0
9.	160	77	122	5.4
10.	161	73	116	5.1
11.	162	56	89	5.0
12.	163	59	95	4.3
13.	163	79	127	5.1
14.	164	64	103	4.8
15.	167	72	117	3.6
16.	167	77	125	7.6
17.	168	71	116	5.9
18.	168	77	126	4.6
19.	170	53	87	2.9
20.	170	57	94	4.5
21.	172	65	108	6.6
22.	172	82	137	6.6
23.	173	56	93	4.3
24.	173	80	133	4.0
25.	174	53	89	3.5
26.	174	64	107	5.5
27.	174	69	116	4.9
28.	174	72	121	5.9
29.	174	79	132	6.3
30.	176	67	113	5.4
31.	177	58	98	4.0
32.	178	75	128	5.8
33.	178	77	131	6.9
34.	178	77	131	6.3
35.	180	53	91	4.4
36.	180	71	122	6.9
37.	182	75	129	5.4
38.	183	47	81	2.9
39.	183	78	135	5.9

TABLE B

CHRONOLOGICAL AGES, INTELLIGENCE SCORES, MENTAL AGES AND ARITHMETIC ACHIEVEMENT SCORES OF THE EXPERIMENTAL PAIRS

Student N=26	Chronological Age (months)	I.Q.	Mental Age (mos.)	Arithmetic Achievement
23	173	56	93	4.3
35	180	53	91	4.6
12	163	59	95	4.3
2	157	62	97	3.9
26	174	64	107	5.5
21	172	65	108	6.6
14	164	64	103	4.8
5	159	69	109	4.1
27	174	69	116	4.9
30	176	67	113	5.4
17	168	71	116	5.9
28	174	72	121	5.9
3	158	77	121	3.4
15	167	72	117	3.6
9	160	77	122	5.4
10	161	73	116	5.1
8	160	76	121	5.0
6	159	76	120	5.0
39	183	78	135	5.9
33	178	77	131	6.9
18	168	77	126	4.6
13	163	79	127	5.1
4	158	79	124	5.1
7	159	80	126	5.0
22	172	82	137	6.6
29	174	79	132	6.3

APPENDIX B

PROBLEM SETS USED IN CONDUCTING STUDY

PROBLEM SHEET ONE

1. Ruth had nine cents. She spent 5 cents for an ice-cream cone. How much money did she have left?

2. Billy had 7 marbles. Today he bought 5 more. How many marbles did he then have?

3. Jack had 45¢. His mother gave him 15¢ more. How much money did Jack have then?

4. Edmonton is 94 miles from Mr. Jones home. One day Mr. Jones drove home from Edmonton. He had a flat tire after he had gone 75 miles. How far was he from his home then?

5. Mrs. Smith made a new dress for Jane. She paid $1.37 for the goods, $.25 for the pattern, $.12 for thread, $.20 for a zipper and $.15 for other materials. How much did the dress cost?

6. Bill's father sometimes drives to Edson on business. It is 127 miles from his home by the road he usually takes. One day he had to make a detour. The trip was then 145 miles. How many miles did the detour add to the trip?

7. Last summer Bill was at camp for 10 days. It cost him $2.50 a day to stay there. How much did it cost him to stay for 10 days?

8. Jim took care of his brother Bill's paper route for 9 days while Bill was at camp. Bill paid Jim $2.25 for his work. This was an average of how much per day?

PROBLEM SHEET TWO

1. There are 36 children in Ruth's class. Fifteen children are boys. How many are girls?

2. If you have 7 cents in your bank and put in 4 more, how many will you have then?

3. Arthur had 65¢. He spent 27¢ for a tool bag for his bicycle. How much money did he have left?

4. Uncle Fred came to visit Sam, Walter and Bill. He brought 45 marbles for the boys. He gave each boy the same number of marbles. How many marbles did he give each boy?

5. Ann's father bought 4 boxes of paper. There were 500 sheets in each box. How many sheets of paper did he buy?

6. Mr. Jones used wood for fuel. He could buy oak blocks for $4.25 a ton. He could also buy 12 inch oak slabs for $4.50 a ton. He bought 3 tons of the oak blocks. How much did he pay for them?

7. Bill had $2.25 to spend. He bought a book about insects for $1.48. How much money did Bill have left then?

8. In this book Bill read that about 625,000 different insects have been named. Some people think there are about 10,000,000 different insects in the world. If this is true, how many have not been named? Is the number of insects that have been named more or less than one million?

PROBLEM SHEET THREE

1. Robert has read 8 books. Frank has read 3 books. How many books have they both read? Robert has read how many more books than Frank?

2. Helen spelled ten words. She missed three of them. How many did she spell correctly?

3. Jim weighs 56 pounds. Phil weighs 93 pounds. Phil weighs how many pounds more than Jim?

4. At the store Jim paid 38¢ for vegetables, 10¢ for bread and 27¢ for sugar. How much did he pay in all for these things?

5. Ray is 11 years old. He is 4 ft. 7 in. tall and weighs 69 lb. How many inches tall is he?

6. The school nurse told Raymond that the average weight of boys of his height and age is 73 lb. How much less than the average does Ray weigh?

7. About 2500 people attended an exhibition of paintings. Of these about 300 were boys and girls. Is this about 1/5, 1/6 or 1/8 of all the people who attended the exhibition?

8. In a recent year bees produced about 14,024 tons of honey on farms in Canada. At $274 a ton, what was the value of the honey produced on Canadian farms that year?

PROBLEM SHEET FOUR

1. Stanley had 9 rabbits. Today he sold three of them. How many rabbits does he have left?

2. Stanley had 8 apples. He ate some of them. If he has two left, how many apples did Stanley eat?

3. Jim bought two pounds of meat for his mother. The meat cost 38¢ a pound. How much did he pay for the meat?

4. Miss Jones had 34 children in her room. She gave each child four sheets of paper. How many sheets of paper did Miss Jones give out?

5. Six members of a stamp club were given 1254 stamps to divide equally among themselves. Each member of the club got how many stamps?

6. Jim won first prize in a corn growing contest. His corn averaged 98 bushels an acre on a 3 acre field, How many bushels of corn did he get from this field?

7. The E.T.S. estimates that it carries on its street cars an average of 21 thousand people per day. Atthis rate, how many thousand people would the E.T.S. carry during the month of July?

8. Mr. Reeve needs a new fence for his chicken yard. The chicken yard is square. Each side of it is 45 feet long. How many feet of fence will he need?

PROBLEM SHEET FIVE

1. Dorothy had 12 doll dishes. She broke some of them. Now she has 7 left. How many did she break?

2. Stan earned 25¢ last week. This week he earned 34¢. How much did he earn in the two weeks?

3. A famous tower is 984 feet tall. The Lee School is 47 feet tall. How much taller is the tower than the school?

4. Mr. Smith sells apples for 5¢ each. How much will he get for a box of 114 apples?

5. Last year 152 books were bought for the eight rooms upstairs. This was an average of how many books per room?

6. At the fruit store Mary bought 3 lb. grapes at 12¢ a pound. She also bought 5 lb. apples at 6¢ a pound. How much did she spend?

7. Helen baked two dozen cookies. She gave 6 cookies to Dorothy. How many cookies did she have left?

8. Mrs. Collins bought 3-3/4 yards of cloth. She used 1-5/8 yard for a blouse and 1 yard for an apron. How much cloth did she have left?

PROBLEM SHEET SIX

1. Bertha owns 14 books. Alice owns some books. Together the girls have 29 books. How many books does Alice have?

2. Bill weighs 58 pounds. John weighs 46 pounds. What is the difference in their weights?

3. When Bill made his kite he used 19 yards of new string. How many feet of new string did Bill use?

4. Mr. Smith spends 54¢ a day on car fare. This is three times as much as Mr. Jones spends. How much does Mr. Jones spend?

5. In 1931 a plane flew across the Atlantic ocean in about 16 hours. In 1942 a plane flew the same route in about seven hours. How many fewer hours did it take to fly this route in 1942 than it did in 1931?

6. There were 32 children in room six. They put an average of 7¢ apiece into the school bank. How much money in all did they put into the school bank?

7. A store bought five crates of oranges. There were 252 oranges in each crate. How many dozen oranges were in each crate?

8. The store sold all the oranges in the five crates at 39¢ a dozen. How much did the store receive for all the oranges?

PROBLEM SHEET SEVEN

1. Bill paid 5¢ for a pencil and 20¢ for a book. How much did he pay for both?

2. Jane is 8 years old. Her sister is 13 years old. How much older is her sister?

3. Tom sold tickets for a play. He sold 5 times as many tickets to children as to parents. He sold 15 tickets to children. How many tickets did he sell to parents?

4. Helen took pictures of her baby brother. She had 32 pictures printed. Each one cost 4¢. How much did all the pictures cost?

5. A fast train travelled 2532 miles in 2 days and 9 hours. In how many hours did the train make the trip?

6. How many miles per hour would the train average during the trip?

7. Jack worked for Mr. Myers for 7 of the 13 weeks of summer holidays. He earned $22.75 and saved $16.85. What was the average amount he earned each week?

8. Did Jack save enough to buy bicycle for $18.75. If not, how much more would he need to buy the bicycle?

PROBLEM SHEET EIGHT

I. Wally has 25 arithmetic problems to do. He has finished 14 of them. How many does he still have to do?

2. Phil saved 27¢ last month and $1.15 this month. How much did he save in the two months?

3. Mary has a piece of cloth 18 inches long. How many doll dresses can she make from this cloth if each dress needs 6 inches of cloth?

4. Elsie's sister wants to make 6 aprons. If she uses two yards of cloth for each apron, how many yards of cloth will she need?

5. Room nine collected pennies for the Red Cross. They collected 217 pennies from 31 children. On the average, how many pennies did they collect from each person?

6. Mrs. Jones ordered 5 dozen white doughnuts at 23¢ a dozen and 3 dozen cake doughnuts at 26¢ a dozen. How many doughnuts in all did she order? (how many doughnuts, not how many dozen doughnuts)

7. How much did she pay in all for the doughnuts?

8. Mr. Smith checks the speedometer of his car often. In February 1960 the speedometer read 12,598 miles. In February 1961, the speedometer read 14,053 miles. How many miles had the car gone from February 1960 to February 1961?

PROBLEM SHEET NINE

1. Bill has fifteen cents. John has twenty five cents. How much money do both boys have?

2. Ralph is 15 years old. His sister is 4 years older than Ralph. How old is Ralph's sister?

3. Bob has 23 blocks to go to school. He has gone 14 blocks at 8:30. How much farther does he have to go?

4. Bill has to walk 12 blocks to school. When he has walked half way, how many blocks has he walked?

5. Three boys in grade four decided to divide 36 candies equally. How many candies would each boy get?

6. A car can travel about 500 miles in a ten hour drive. What would be the average speed in miles per hour of this car?

7. Mr. Ross bought two chickens. One weighed 3 lb. 4 oz. The other chicken weighed 2 lb. 10 oz. How much heavier was the first chicken?

8. A grocer sold apples at four pounds for 25¢. How many pounds of apples could you buy for 75¢?

PROBLEM SHEET TEN

1. Joe had 24¢ and bought a toy that cost 16¢. How much money would' he have left?

2. Frank had 17 pictures of airplanes. Bill had 24 pictures of airplanes. How many pictures did the two boys have?

3. Mary had 24 cookies. If she wanted to share them equally among 4 girls, how many cookies would each girl get?

4. Mary wanted to give each of her five friends three pieces of candy. How many pieces of candy would she need?

5. Eight rooms collected $6.40 for the Red Cross. One of these rooms collected 40¢. What was the average amount each room collected?

6. A boy bought 3 dozen doughnuts for 60¢ a dozen and 4 dozen cookies at 40¢ a dozen. How many cookies and doughnuts did he buy?

7. How much would this boy pay for all the doughnuts?

8. The boy gave the baker a $5.00 bill. How much change would he receive after paying for the doughnuts and the cookies?

PROBLEM SHEET ELEVEN

1. Tom had 18 cents. Then his father gave him a dime. How much money does he have now?

2. Bill had 34 cents. Then he spent some money. Now he has 18 cents. How many cents did Bill spend?

3. Mary bought ten 2 cent stamps for Christmas cards. How much did the stamps cost?

4. 3 apples cost ten cents. How many apples could you buy for 40 cents?

5. A train can travel 2160 miles in three days. What would be the train's average speed in miles per hour?

6. One turkey weighed 14 lb. 12 oz. Another turkey weighed 16 lb. 8 oz. How much heavier was the second turkey?

7. Bill has 7 marbles. John has 28 marbles. How many times as many marbles as Bill has John?

8. A lot is 60 feet wide and 150 feet long. How many yards of fencing are needed to build a fence around the lot?

PROBLEM SHEET TWELVE

1. John had 18 crayons. Then he lost four crayons. How many crayons does he have left?

2. Bill and Tom each earned $2.40 shovelling snow. How much did the two boys earn together?

3. Bill spent some of his money and then had $1.65 left. How much money did he spend?

4. Tom bought three pounds of Candy at 58 cents a pound with his money. How much money did he have left?

5. The lunchroom has places for 112 children at one time, seated 8 at a table. How many tables are there?

6. A lawn is 40 feet long and 35 feet wide. What is the distance around the lawn?

7. Jack earned $5.86 one week, $7.28 the next week, $6.75 the third week and $6.95 the fourth week. What was the average amount he earned each week?

8. Fred is nine years old. His aunt is five times as old as Fred. How old is Fred's aunt?

PROBLEM SHEET THIRTEEN

1. Tom bought 15 firecrackers. He has shot off 9 of them. How many firecrackers has he left?

2. Jack attended school 18 days last month and 16 days this month. How many days has he attended school in the two months?

3. When Jerry's brother came home on leave, he spent 12 hours on the train. He spent $\frac{1}{2}$ that many hours on the bus. How many hours did he spend on the bus?

4. When Ben's father changes the oil in his car, he puts in 6 quarts of oil that cost 55¢ a quart. How much does this oil for the car cost?

5. During July, Bill sold apple juice at a roadside stand. One day he sold 64 quarts of apple juice. How many gallons would this be?

6. Mr. Jones has 27 steers on his farm. Every day he feeds about 14 lb. of corn, 20 lb. of silage, 2 lb. of hay and 2 lb. of cottonseed meal to a steer. How many pounds of feed does he use each day for a steer?

7. About how many pounds of feed would he use each day for all the steers?

8. About how many pounds of corn would he need for all his steers in one week?

PROBLEM SHEET FOURTEEN

1. Billy has three dimes, five nickels and two quarters. How many coins does he have?

2. How much money does Billy have?

3. A plane can travel at an average speed of 478 miles per hour. How far can this plane travel in three hours?

4. Three boys who were playing ball broke a window. This window costs $4.80 to replace. If the boys decided to share the expense equally, how much was each boys' share?

5. Five girls have a picnic, and shared the cost of the food. They spent 25¢ for sandwiches, 20 cents for apples, and 15 cents for candy. How much would each girl's share of the expense be?

6. Larry gave a $1.00 bill to the grocer to pay for 6 lb. of sugar at 12¢ a pound. How much change did he get back?

7. It takes a boy 23 minutes to walk to school. If he leaves home at 8:39 a.m. when he gets to school what time will it be? If school starts at 9:00 a.m., will he be late?

8. A lawn is 50 feet long and 40 feet wide. 1 pound of grass seed will cover 200 square feet. How many pounds of grass seed do you need to seed this lawn?

PROBLEM SHEET FIFTEEN

1. A boy found 5 eggs in one nest, 6 eggs in the second nest and a dozen eggs in a third nest. How many eggs did he find in all?

2. If eggs cost 50¢ a dozen, how much would 36 eggs cost?

3. A boy bought a knife on sale for 68¢. The regular price of the knife was 87¢. How much money did the boy save?

4. If he gave the storekeeper a $5.00 bill, how much would he get in change after buying the knife?

5. If a car can travel at an average speed of 45 miles per hour, how many hours will it take to travel 225 miles?

6. A girl bought five pounds of grapes at 6¢ a pound, three pounds of apples at 5¢ a pound and six pounds of bananas at 10¢ a pound. How many pounds of fruit did she buy?

7. How much did this girl pay for all the fruit she bought?

8. A car can travel about 100 miles per hour in a race. A horse can run about 35 miles per hour for a short distance. A jet plane can fly 1000 miles per hour. How many times as fast as the car is the jet plane?

PROBLEM SHEET SIXTEEN

1. Bill has five cents. He wants to buy a top for 10¢. How much more money must he save before he can buy the top?

2. Mother had 7 eggs left after baking a cake. How many less than a dozen was this?

3. There are ten windows on Joan's house. Joan can wash one of them in five minutes. How many minutes would it take Joan to wash seven of the windows?

4. Mary's mother baked 45 cookies in three pans. She put the same number of cookies into each pan. How many cookies did she put in each pan?

5. At a doll show, Ann won the prize given for the oldest doll. Her doll was made in 1865. How old was Ann's doll?

6. At a fair, the tallest stalk of corn was 8 feet, 9 inches tall. How many inches tall was it?

7. Laura uses $\frac{1}{2}$ cup of milk to make 6 muffins. At this rate, how many cups of milk must she use to make 24 muffins?

8. Jerry's father is having a cement floor put in his garage. The floor will be 18 feet long and 12 feet wide. How much will it cost at $2.25 per square yard?

PROBLEM SHEET SEVENTEEN

1. Bill bought postcards at 2 cents each. How much must Bill pay for five postcards?

2. Harry has 24 stamps on each page of his stamp book. There are 9 pages in his stamp book. There are three rows of stamps on each page. How many stamps are there in each row?

3. Tickets for a show cost 18 cents each. How much would you have to pay for three tickets?

4. There are 16 boys and 24 girls in a class. If all the boys and one half of the girls took part in a play, how many children took part in the play?

5. Don bought ½ dozen cookies at 30¢ a dozen, and ½ dozen cupcakes at five cents each. How much did the cookies and cupcakes cost altogether?

6. Last month Peter's hens laid 168 eggs. If eggs are worth 50¢ a dozen, how much would Peter earn by selling these eggs?

7. Mrs. Jones planted 72 bulbs in her garden. 5/8 of these bulbs tulip bulbs. How many tulip bulbs did Mrs. Jones plant?

8. How many feet of weatherstripping would you need to go around a window that is 24 inches wide and 54 inches high?

PROBLEM SHEET EIGHTEEN

1. Two boys went to a show. Each boy paid 15¢ for his show ticket, and five cents for a bag of popcorn. How much did the two boys spend altogether?

2. Jimmy bought five pencils for 35¢. How much did each pencil cost?

3. Bill had two dollars. He spent 15¢ for a ruler, 35¢ for books and 75¢ for crayons. How much change did he get back from his $2.00?

4. Mary could buy three oranges for 25¢. How many oranges could she buy for $1.00?

5. Bill lives twenty blocks from school. Fred lives 5 blocks from school. How many times as far as Fred does Bill live from school?

6. Potatoes are worth $2.00 a bushel. There are 60 lb. of potatoes in one bushel. How much would 420 lbs. potatoes be worth?

7. Edson is 130 miles from Edmonton. Jasper is 236 miles from Edmonton. Kamloops is 508 miles from Edmonton. How far is it from Jasper to Kamloops?

8. A fence is 8 feet high and 150 feet long. One can paint will cover 200 square feet. If the paint costs $2.50 per can, how much will it cost to paint the fence?

PROBLEM SHEET NINETEEN

1. Jim had three dimes, 7 nickels and 4 quarters. How many coins did Jim have?

2. How much money did Jim have?

3. If a man had 64 horses, 39 sheep and 47 cows, how many more cows than sheep would he have?

4. Pencils cost 5¢ each and rulers cost 15¢ each. How many pencils could you buy for the price of one ruler?

5. Bill measured the distance around a square sheet of paper. The total distance around the sheet of paper was 36 inches. How long was each side?

6. A man can walk 4 miles per hour. How far can he walk at this rate in $3\frac{1}{2}$ hours?

7. At this rate, how long would it take this man to walk 20 miles?

8. A farmer had 40 acres of wheat. The field yielded 28 bushels per acre. If wheat is worth $1.12 per bushel, how much did the farmer get for all his wheat?

PROBLEM SHEET TWENTY

1. Billy has 8 marbles. Tom has one half as many marbles as Billy. How many marbles has Tom?

2. Two boys together have 84 cents. One boy has 29 cents. How much money does the other boy have?

3. Joe is building a doghouse. The doghouse is 4 feet long. How many 4 foot lengths of board can he cut from a 12 foot board?

4. Three cans of beans cost 39¢. How much change would you get from $1.00 if you bought one can of beans?

5. A car travels 20 miles on one gallon of gasoline. Gasoline costs 43¢ a gallon. How much gasoline will you need to drive 200 miles?

6. John made 60, 80, 75 and 65 on four arithmetic tests. What was his average mark?

7. Billy delivers papers. He earns 2¢ for each paper he delivers. He delivers 47 papers each day. How much does he earn in one week?

8. A farmer built a three wire fence around a field 150 yards long and 100 yards wide. How many yards of fence wire did he need?

PROBLEM SHEET TWENTY-ONE

1. Jim has 8 cents. Bill has 7 cents more than Jim. How much money has Bill?

2. How much money do the two boys have together?

3. It takes Bob one hour to walk to school. Harold can walk to school in 10 minutes. How many minutes longer does it take Bob to walk to school than it takes Harold?

4. Wally can walk 18 blocks in 10 minutes. How far can he walk in one hour at this rate?

5. Each week Brian puts 87¢ into his bank. How long would it take Brian to save enough to buy a shirt that costs $4.35?

6. How much money would Brian save in 9 weeks?

7. The distance around a field is 600 yards. The field is 100 yards wide. How long is the field?

8. On a holiday trip the Smiths drove 450 miles in one day. If their car goes an average of 20 miles per gallon of gasoline, and gasoline is worth 38¢ a gallon, what was the cost of the gasoline that the Smiths used that day?

PROBLEM SHEET TWENTY-TWO

1. Ann had 12 dolls. Jane had 5 dolls fewer than Ann. How many dolls did Jane have?

2. How many dolls did the two girls have altogether?

3. Bill has 84 marbles. Fred has 69 marbles. Joe has 75 marbles. How many marbles do the three boys have altogether?

4. How many more marbles than Fred has Joe?

5. John is $63\frac{1}{2}$ inches tall. What is his height in feet and inches?

6. Bill earned $18.00 one week. The next week he earned two times that much. What was the average amount he earned each week?

7. Gerald sold 8 candy bars and Brian sold 4 candy bars. The candy bars sell for 50¢ each. How much money did Gerald and Brian get altogether for the candy bars they sold?

8. Mr. Jones built a fence around his lot that cost $200.00. The fence cost 50¢ per foot. Mr. Jones' lot is 150 feet deep. How wide is the lot?

PROBLEM SHEET TWENTY-THREE

1. Jim has 3 nickels, 2 dimes and one quarter. How many coins has he?

2. How much more is the quarter worth than the two dimes?

3. If John has 87¢ and he and Bob together have $1.35, how much money has Bob?

4. If Bill has 8 marbles and Fred has 3 less than Bill, how many marbles do the two boys have altogether?

5. Butter costs 71¢ per pound. How much must Joe pay for 6 lb. of butter?

6. Joe buys some roast pork that cost 57¢ a pound. The total cost of the meat was $2.28. How many pounds of meat did he buy?

7. If a boy was 4 feet $10\frac{1}{2}$ inches tall, how many inches tall would he be?

8. If three boys each earn $2.50 a day helping at a store after school, how many days will the three boys have to work to earn $67.50?

PROBLEM SHEET TWENTY-FOUR

1. A boy had ten cents. He spends 4 cents for candy. Then he finds a penny on the ground. How much money has he now?

2. Three cans of apple juice cost $1.23. How much would one dozen cans cost?

3. Billy has three dozen marbles. Fred has 17 marbles. How many marbles do the two boys have altogether?

4. Eggs are worth 70¢ a dozen. How much would you pay for one half dozen eggs?

5. If a car can travel 20 miles on one gallon of gasoline, and if gasoline sells for 42¢ per gallon, how much would the gasoline for a 600 mile trip cost?

6. One week Joe earned $7.50, the next week he earned $9.00 and the third week he earned $6.00. What were his average weekly earnings?

7. The area of a garden is 1500 square feet. The length of this garden is 50 feet. Find the width of the garden.

8. Bill is one half as old as John. John will be 25 years old next winter. How old is Bill?

PROBLEM SHEET TWENTY-FIVE

I. If a kangaroo can jump 18 feet in one jump, how far could he jump in three jumps?

2. A boy spends ten cents for candy, thirty five cents for books and a nickel for gum. How much change will he get from a dollar?

3. One dozen oranges cost 68 cents. How much would one half dozen cost?

4. What is the distance around a field that is 38 rods long and 50 rods wide?

5. A train can travel 720 miles in one day. What is the average speed in miles per hour of this train?

6. Bill got a puppy for Christmas. The puppy weighed 5 lb. 4 oz. How many ounces did the puppy weigh?

7. A boy can walk 36 blocks in one hour. How many blocks can he walk in 45 minutes?

8. A lot is 50 feet long and 30 feet wide. If one pound of grass seed will seed 300 square feet, how much would it cost to seed this lawn if grass seed is worth $1.00 per pound?

APPENDIX C

1. STATISTICAL ANALYSIS OF DIFFERENCES BETWEEN GAINS USING WALSH TEST.
2. TABLE OF CRITICAL VALUES FOR WALSH TEST.

STATISTICAL ANALYSIS OF DIFFERENCES BETWEEN GAINS USING WALSH TEST

Differences between grade placement score gains on the Arithmetic Reasoning portion of the C.A.T., N = 13.

Max. $\left[\frac{1}{2}(-8 + 22) = 7,\ \ \frac{1}{2}(-7 + 8) = \frac{1}{2}\right]$ is not less than 0.

Min. $\left[\frac{1}{2}(-22 + 3) = -9.5,\ \ \frac{1}{2}(-12 + 1) = -5.5\right]$ is not greater than 0.

Therefore, H_o is not rejected at the .047 level of significance.

Differences between gains in number of problems correctly solved in Arithmetic Reasoning portion of C.A.T., N = 13.

Max. $\left[\frac{1}{2}(-2 + 2) = 0,\ \ \frac{1}{2}(-2 + 2) = 0\right]$ is equal to but not less than 0.

Min. $\left[\frac{1}{2}(-6 + -2) = -4,\ \ \frac{1}{2}(-5 + -2) = -3.5\right]$ is not greater than 0.

Therefore, H_o is not rejected at the .047 level of significance.

Differences between grade placement score gains on the grade three Problem Solving section of the Iowa Tests of Basic Skills. N = 13.

Max. $\left[\frac{1}{2}(-9 + 10) = \frac{1}{2},\ \ \frac{1}{2}(-8 + 5) = -1.5\right]$ is not less than 0.

Min. $\left[\frac{1}{2}(-20 + 2) = -9,\ \ \frac{1}{2}(-12 + 1) = -5.5\right]$ is not greater than 0.

Therefore, H_o is not rejected at the .047 level of significance.

Differences between grade placement score gains on the grade five Problem Solving section of the Iowa Tests of Basic Skills, N = 11.

Max. $\left[1\ ,\ \ \frac{1}{2}(-5 + 4) = -\frac{1}{2}\right]$ is not less than 0.

Min. $\left[-5\ ,\ \ \frac{1}{2}(-18 + 1) = -8.5\right]$ is not greater than 0.

Therefore, H_o is not rejected at the .056 level of significance.

TABLE C

TABLE OF CRITICAL VALUES FOR THE WALSH TEST

No. of Pairs	Significance Level of Test Two-Tailed	Tests Two-Tailed: if either	Reject null-hypothesis or
N=11	.097	Max. $\left[d_7, \frac{1}{2}(d_4 + d_{11})\right] < 0$	Min. $\left[d_5, \frac{1}{2}(d_1 + d_8)\right] > 0$
	.056	Max. $\left[d_7, \frac{1}{2}(d_5 + d_{11})\right] < 0$	Min. $\left[d_5, \frac{1}{2}(d_1 + d_7)\right] > 0$
	.021	Max. $\left[\frac{1}{2}(d_6 + d_{11}), \frac{1}{2}(d_8 + d_9)\right] < 0$	Min. $\left[\frac{1}{2}(d_1 + d_6), \frac{1}{2}(d_3 + d_4)\right] > 0$
	.011	Max. $\left[d_9, \frac{1}{2}(d_7 + d_{11})\right] < 0$	Min. $\left[d_3, \frac{1}{2}(d_1 + d_5)\right] > 0$
N=13	.094	Max. $\left[\frac{1}{2}(d_4 + d_{13}), \frac{1}{2}(d_5 + d_{12})\right] < 0$	Min. $\left[\frac{1}{2}(d_1 + d_{10}), \frac{1}{2}(d_2 + d_9)\right] > 0$
	.047	Max. $\left[\frac{1}{2}(d_5 + d_{13}), \frac{1}{2}(d_6 + d_{12})\right] < 0$	Min. $\left[\frac{1}{2}(d_1 + d_9), \frac{1}{2}(d_2 + d_8)\right] > 0$
	.020	Max. $\left[\frac{1}{2}(d_6 + d_{13}), \frac{1}{2}(d_8 + d_{10})\right] < 0$	Min. $\left[\frac{1}{2}(d_1 + d_8), \frac{1}{2}(d_4 + d_5)\right] > 0$
	.010	Max. $\left[d_{10}, \frac{1}{2}(d_7 + d_{13})\right] < 0$	Min. $\left[d_4, \frac{1}{2}(d_1 + d_7)\right] > 0$

Adapted from Walsh, J. E., 1949 and cited in *Nonparametric Statistics for the Behavioural Sciences*, Sidney Siegel, New York: McGraw-Hill Book Company, Inc., 1956. Page 255.

APPENDIX D

ANALYSIS OF DIFFERENCES BETWEEN GAINS USING A T-TEST

ANALYSIS OF DIFFERENCES BETWEEN GAINS USING T-TEST

A method for testing the significance of the difference between two means for correlated samples, sometimes called the difference method, is described by Ferguson.[***] This method makes use of the t-test, treats the differences as a variable and tests the difference between the mean of this variable and zero.

The variance of the differences (d's) is given by

$$S_d^2 = \sum d^2 / N - \bar{d}^2$$

where $\sum d^2$ is the sum of the squares of the differences, N is the number of pairs of observations and $\bar{d}$ is the mean difference, which is equal to the difference between the two means.

An estimate of the variance of the sampling distribution of $\bar{d}$, using an unbiased estimate of the population variance, is

$$S_{\bar{d}}^2 = S_d^2 / N - 1$$

The appropriate t ratio is obtained by dividing $\bar{d}$ by $S_{\bar{d}}$. Thus

$$t = \bar{d} / S_{\bar{d}} = \frac{\bar{d}}{\sqrt{S_d^2 / (N-1)}}$$

[***] George A. Ferguson, Statistical Analysis in Psychology and Education, (Toronto: McGraw-Hill Book Company, Inc., 1959), pp. 138-139.

The number of degrees of freedom used in evaluating t is one less than the number of pairs of observations, or N - 1.

Using the data of Table VIII we may calculate the required variances and t-ratios to be tested.

1. Difference between mean gains on Arithmetic Reasoning portion of C.A.T.

$$\bar{d} = -1.69 = d/N = -22/13$$

$$\sum d^2 = 1542$$

$$S_d^2 = 1542/13 - (-1.69)^2 = 115.76$$

$$t = \pm 1.69/\left(115.76/12\right)^{\frac{1}{2}} = \underline{1.69/3.11} = \underline{.54}$$

(For a two-tailed test the absolute magnitude of $\bar{d}$ is required.)

For 13-1 = 12 degrees of freedom, a value of 2.179 or greater would be needed before the differences between means could be considered significant at the .05 level (for a two-tailed test).

2. Difference between mean gains in number of problems solved correctly in Arithmetic Reasoning portion of C.A.T.

$$\bar{d} = -21/13 = -1.61 \qquad N = 13$$

$$\sum d^2 = 135$$

$$S_d^2 = 135/13 - (-1.61)^2 = 7.79$$

$$t = 1.61/\left(7.79/12\right)^{\frac{1}{2}} = 1.61/.79 = \underline{2.03}$$

For 12 degrees of freedom, a t = 2.179 is required before the mean difference (using a two-tailed test) can be considered significantly different from zero, at the .05 level of significance.

3. Difference between mean gains on grade three problem solving section of the Iowa Tests of Basic Skills.

$$\bar{d} = -45/13 = -3.46 \quad N = 13$$
$$\sum d^2 = 1045$$
$$S_d^2 = 1045/13 - (-3.46)^2 = 68.41$$
$$t = 3.46/(68.41/12)^{\frac{1}{2}} = 3.46/2.39 = 1.45$$

For 12 degrees of freedom, a t = 2.179 is required before the mean difference can be considered as being significantly different from 0.

4. Difference between mean gains on grade five problem solving section of the *Iowa Tests of Basic Skills*.

$$\bar{d} = -39/11 = -3.54 \quad N = 11$$
$$\sum d^2 = 1107$$
$$S_d^2 = 1107/11 - (-3.54)^2 = 88.11$$
$$t = 3.54/(88.11/10)^{\frac{1}{2}} = 3.54/2.96 = 1.2$$

For 10 degrees of freedom, t = 2.228 is required before the difference between mean gains is significantly different from zero, at the .05 level of significance.

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